Parametric Study of CNC Turning on Surface Quality of AA5083/SIC-TIO2 Metal Matrix Composite

James Bennett*[1], Adeel Tariq Malik[2] & Oliver Smith[3]
[*1,3]Assistant Professor, Department of Engineering, University of Cambridge, Cambridge, United Kingdom
[*2]M.Tech Student, Department of Engineering, University of Cambridge, Cambridge, United Kingdom

ABSTRACT

In present work, an attempt has been made to experimental investigate the machinability of aluminum metal matrix composite during continuous turning of composite bars using carbide inserts. The aluminum metal matrix composite was fabricated by stir casting process. Base matrix material is Aluminum Alloy 5083 reinforced with 10wt% silicon carbide particles and 3wt % of TiO2 of mean diameter 20 µm to 40 µm is used. Experiments has been performed on CNC Turning center by using carbide insert at various cutting conditions and parameters such as cutting speed, feed and depth of cut and surface roughness was found at different levels. The effect of machining parameters, e.g. cutting speed and depth of cut on the surface roughness has been discussed.

KEYWORDS: Aluminum metal matrix composite, Surface roughness (SR), CNC Turning Center.

1. INTRODUCTION

Many of our modern technologies require materials with unusual combinations of properties that cannot be met by the conventional metal alloys, ceramics and polymeric materials This is especially true for materials that are needed for aerospace, underwater and transportation applications. Considerable research in the material science has been directed toward the development of new engineering materials possessing high strength to weight ratio, high specific strength, stiffness at elevated temperatures, good creep, fatigue and wear resistance. Advanced automotive and aerospace technology requires improved performance of these materials. These properties are not achievable with conventional monolithic materials. As a result of intensive studies into the fundamental nature of materials and better understanding of their structure property relationship, it has become possible to develop new composite materials with improved physical and mechanical properties. Metals, ceramics, glasses, polymers and cement can be combined in composite materials to produce unique characteristics. These materials have low specific gravity that makes their properties particularly superior in strength and modulus to many traditional engineering materials. Favorable properties of composites materials are high stiffness and high strength, low density, high temperature stability, high electrical and thermal conductivity, adjustable coefficient of thermal expansion, corrosion resistance, improved wear resistance etc. Continuous advancements have led to the use of composite materials in more and more diversified applications [1]. The importance of composites as engineering materials is reflected by the fact that out of over 1600 engineering materials available in the market today more than 200 are composite. Aluminum metal matrix composites refer to the class of light weight aluminum centric systems which are characterized by superior physical and mechanical properties. An advantage of using these materials than the non-reinforced aluminum alloys can be attributed to the fact that properties of aluminum metal matrix composites can be tailored to the demands of different industrial applications by suitable combinations of aluminum matrix, reinforcement and processing route. Although, the presence of ceramic reinforcements in these materials likes SiC, Al_2O_3, etc improve stiffness, hardness; wear resistance, etc as desired in typical industrial applications, but also makes machining like turning difficult.

2. MATERIAL PREPARATION

The matrix material used in this study is AA 5083 (Figure 2.1). Table 2.1 shows the chemical composition of AA5083. The reinforcement material added was Sic & TiO_2 (Figure 2.2 & 2.3). AA 5083 was properly cleaned prior to melting to eliminate any impurities on the surface. It was then heated In the graphite crucible. A furnace heating temperature was set to 725ºC, and maintained for 60 minutes until Aluminum alloy melted completely.

Aluminum dross were then removed from the surface of the molten metal with the help of a laddle. The stirrer position was kept; such that 35% of material was below the stirrer and 65% of material was above the stirrer. A determined quantity of particulate Titanium Dioxide and Silicon Carbide as per percentage requirement in the composite; was preheated to 650ºC in drying oven for improving wettability. Preheated reinforcement was added continuously to the molten metal and stirring of mixture was carried out. The optimum stirring speed of 300 rpm was arrived at by conducting number of experiments. This is to avoid excessive gas content that results from over agitating of melts, which leads to unacceptable porosity content in the casting product. The stirrer and stirring rod was coated with TiO_2 so as to avoid any metals contamination to the molten metal.

Figure 2.1 Aluminum Alloy 1100

Figure 2.2 Silicon Carbide Powder

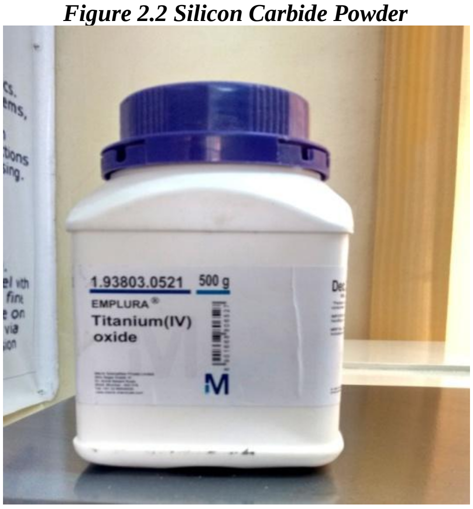


Figure 2.3 Titanium Oxide Powder

Stirring was carried out to facilitate both incorporation and uniform distribution of particulate in the molten metal. The composite melt was stirred up till full mixing of powder into the molten metal. The crucible was taken out of the furnace with the help of tong, then immediately cast into a preheated sand mould. Molten mixture was poured in the mould.The molten mixture was allowed to cool in the mould and was let to solidify; hence rods of diameter 25mm were obtained.

Table 2.1 Chemical composition of AA 5083

Alloy	Si+ Fe	Cu	Mn	Mg	Zn	Ti	Cr	Al
5083	0.80 Si+Fe	0.01	0.4-1.0	4.0-4.9	0.25	0.15	0.05-0.25	Balance

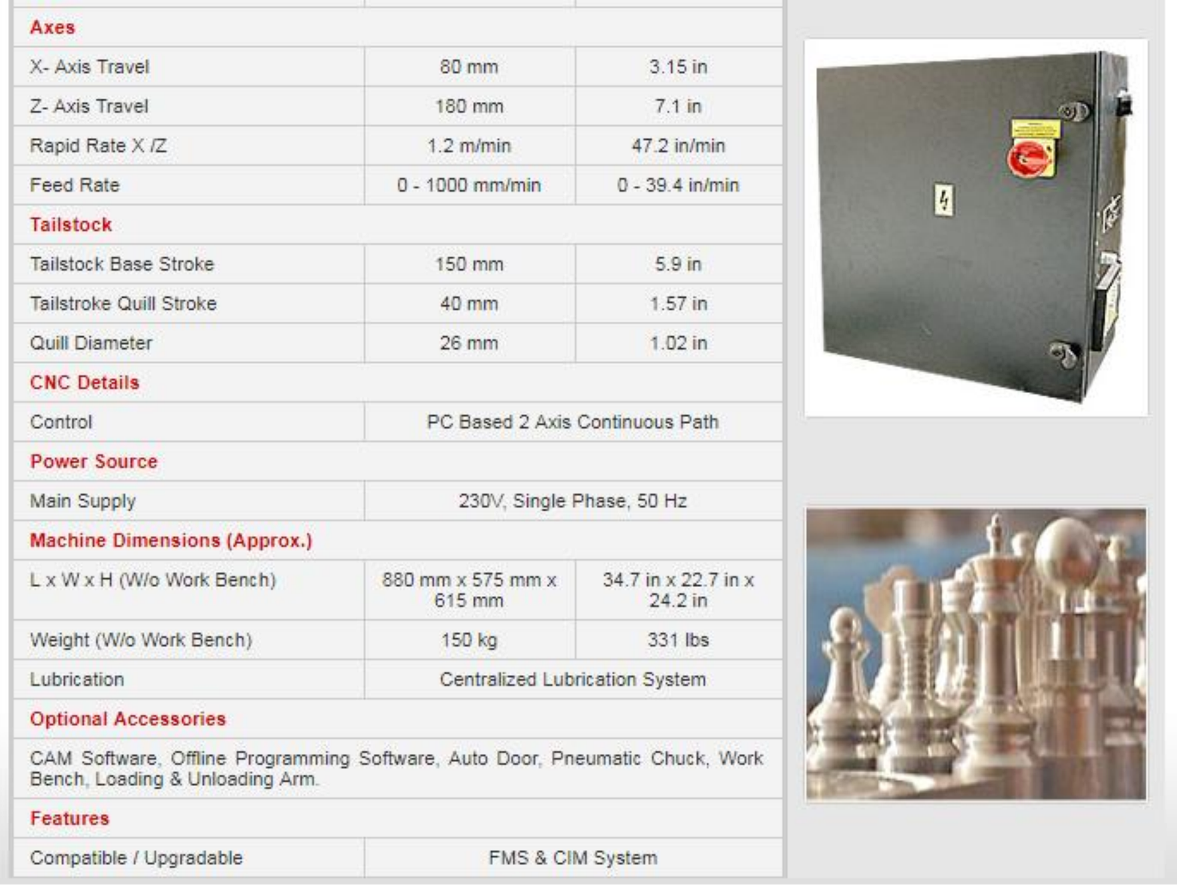
3. EXPERIMENTAL WORK

The main objective of this experimental work was to study the effect of Spindle speed, feed, and depth of cut in CNC turning of AA 5083/SiC-TiO_2 composite for surface roughness and investigate the surface roughness after machining. To study the effect on surface roughness, various parameters and levels selected are listed in Table 3.2.

Figure 3.1 MTAB CNC Flexturn Turning Centre

Table 3.1 Technical Specifications of CNC Turning Centre

Capacity		
Chuck Size	100 mm	3.94 in
Maximum Turning Diameter	32 mm	1.26 in
Maximum Turning Length	120 mm	4.72 in
No. of Axes	2	
Swing Over Bed	150 mm	5.9 in
Swing Over Crosslide	50 mm	1.97 in
Distance between Centers from Spindle Face	210 mm	8.27 in
Spindle		
Spindle Nose Taper	A2-3 / MT3	
Hole through Spindle	20 mm	0.79 in
Spindle Speed Range	150 - 3000 RPM	
Spindle Motor Capacity	1 HP	
Turret & Tooling		
Number of Stations	8	
Tool Cross Section	12 mm x 12 mm	0.47 in x 0.47 in



Axes		
X- Axis Travel	80 mm	3.15 in
Z- Axis Travel	180 mm	7.1 in
Rapid Rate X /Z	1.2 m/min	47.2 in/min
Feed Rate	0 - 1000 mm/min	0 - 39.4 in/min
Tailstock		
Tailstock Base Stroke	150 mm	5.9 in
Tailstroke Quill Stroke	40 mm	1.57 in
Quill Diameter	26 mm	1.02 in
CNC Details		
Control	PC Based 2 Axis Continuous Path	
Power Source		
Main Supply	230V, Single Phase, 50 Hz	
Machine Dimensions (Approx.)		
L x W x H (W/o Work Bench)	880 mm x 575 mm x 615 mm	34.7 in x 22.7 in x 24.2 in
Weight (W/o Work Bench)	150 kg	331 lbs
Lubrication	Centralized Lubrication System	
Optional Accessories		
CAM Software, Offline Programming Software, Auto Door, Pneumatic Chuck, Work Bench, Loading & Unloading Arm.		
Features		
Compatible / Upgradable	FMS & CIM System	

Figure 3.2 Cast AA 5083/SiC-TiO₂

Table 3.2 Parameters and level selection

Spindle Speed(rpm)	500	1000	1500	2000	2500
Feed (mm/rev)	0.01	0.02	0.03	0.04	0.05
D.O.C (mm)	0.1	0.3	0.5	0.7	0.9

4. RESULTS AND DISCUSSIONS

Work piece material Aluminum Alloy 5083 reinforced with Sic and TiO_2 particles composition is already shown above. It has got low thermal expansion and good wear resistance. It is observed that while machining AA 5083/SiC-TiO_2 work piece, discontinuous chips are formed. Experimental data related to surface roughness characteristics three graphs are plotted using MS-Word 2007 software application.

Table 4.1 Varying the Speed (Feed and DOC constant)

NO.	SPINDLE SPEED(rpm)	FEED(mm/rev)	DOC(mm)	SR(Ra) µm
1	500	0.03	0.5	3.108
2	1000	0.03	0.5	2.742
3	1500	0.03	0.5	1.993
4	2000	0.03	0.5	1.890
5	2500	0.03	0.5	1.858

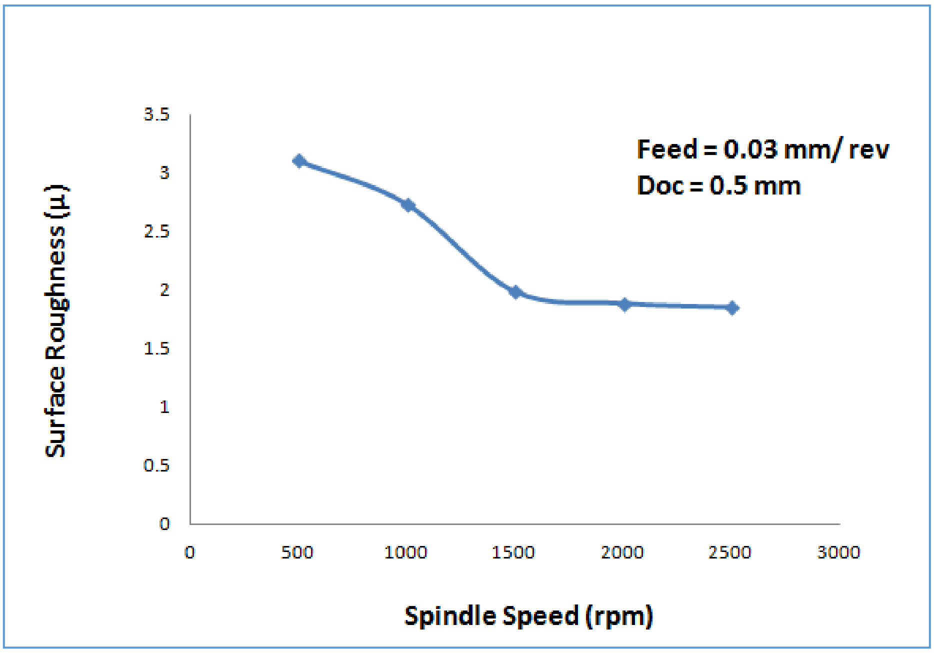


Figure 4.1 Change of surface roughness with spindle speed

It is seen from the graph of Surface roughness Vs. Spindle Speed that when feed & depth of cut are kept constant and only Spindle speed is increased continuously we can see from the graph that when the value of spindle speed is 500 rpm the value of surface roughness is very high (3.108µm) but when the spindle speed is increased SR decreases sharply upto 1500 rpm and the decrease in SR is low. The minimum value of surface roughness (1.858µm) can be achieved when the Spindle speed is at 2500 rpm.

Table 4.2 Varying the Feed (Spindle Speed and DOC constant)

NO.	SPINDLE SPEED(rpm)	FEED(mm/rev)	DOC(mm)	SR(Ra) µm
1	1500	0.01	0.5	3.967
2	1500	0.02	0.5	3.501
3	1500	0.03	0.5	4.231
4	1500	0.04	0.5	4.575
5	1500	0.05	0.5	5.631

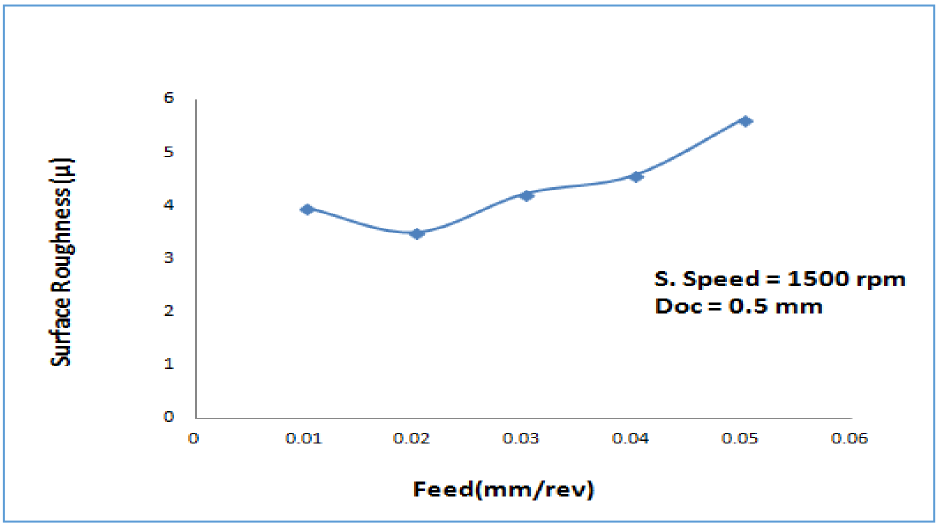


Figure 4.2 change of surface roughness with feed gradually

Figure 4.2 shows the change of Surface roughness with the increase in feed. It is seen from the graph of Surface roughness Vs. feed that when Spindle speed and depth of cut are kept constant and only feed is increased surface roughness increases gradually.

Table 4.3 Varying the D.O.C (Spindle Speed and Feed constant)

NO.	SPINDLE SPEED(rpm)	FEED(mm/rev)	DOC(mm)	SR (Ra) µm
1	1500	0.03	0.1	2.374
2	1500	0.03	0.3	2.554
3	1500	0.03	0.5	3.785
4	1500	0.03	0.7	4.961
5	1500	0.03	0.9	6.937

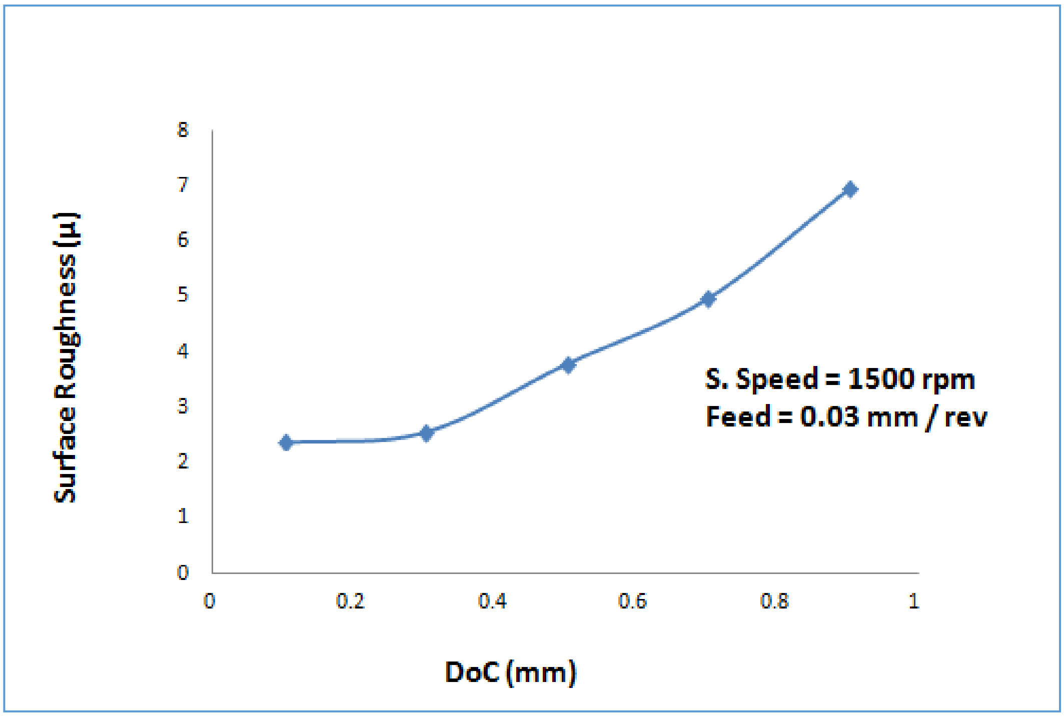


Figure 4.3 change of surface roughness with depth of cut

Figure 4 shows the curve between surface roughness and depth of cut. The surface increases with increase in depth of cut. The increase in surface roughness is gradual from 0.3 mm to 0.9 mm depth of cut.

5. CONCLUSION

In this work, effects of SiC-TiO_2 reinforcement to AA 5083 on surface roughness during turning have been investigated in terms of selected parameters such as cutting speeds, feed rates, and depth of cuts. For optimum surface roughness in the workpiece, it is recommended that turning operation on Al alloy composite by carbide insert should be carried out at, cutting speed within the range of 1500 to 2500 m/min, feed rate within range of 0.02 mm/rev, and DOC within range of 0.1 to 0.3 mm.

Among all the cutting parameters affecting surface roughness of the Al composite (AA 5083/SiC-TiO_2), surface roughness shows decreasing trend sharply as the cutting speed increases. Cutting speed and depth of cut has maximum effect.

REFERENCES

[1] Kapil Singh & Rajesh Kumar Bhushan (2017) “ Effect of process parameters on surface roughness in face milling of AA1100/10wt%ZrO2 MMC” International Journal of Science & Research Vol 6, Issue 6, ISSN: 2319-7604.

[2] Rajesh Kumar Bhushan & Sudhir Kumar & S. Das, (2010) “Effect of machining parameters on surface roughness and tool wear for 7075 Al alloy SiC composite”,Int J Adv Manuf Technol (2010) 50:459–469

[3] .N. Muthukrishanan, & P.J. Davim, (2008) “Optimization of machining parameters of Al/SiC-MMC with ANOVA and ANN analysis”, Journal of materials processing technology.

[4] M. El-Gallab, M. Sklad (1998), “Machining of Al:SiC particulate metal matrix composites Workpiece surface integrity”, Journal of Materials Processing Technology 83 277–285

[5] N. Muthukrishnan & M. Murugan (2007), “Machinability issues in turning of Al-SiC (10p) metal matrix composites”, Springer-Verlag London Limited.

[6] X. Ding, WYH Liew, XD Liu (2005) “Evaluation of machining performance of MMC with PCBN and PCD tools”, Wear 259:1225–1234

[7] A. Manna, B. Bhattacharayya (2005) “Influence of machining parameters on the machinability of particulate reinforced Al/SiCMMC”, Int J Adv Manuf Technol 25:850–856

[8] T. Ozben, E. Kilickap, O. Cakir (2008) “Investigation of mechanical and machinability properties of SiC particle reinforced Al-MMC”, Journal of Materials Processing Technology.

[9] Singh, S., Singh, K. and Bhushan, R.K. (2012) “Machining Response in Turning Aluminum composite LM13 With 15% SiC”, International Journal of enhanced Research in Science Technology

& Engineering, VOL. 1 Issue 1.

[10] Arokiadass, R. Palaniradja, K. and Alagumoorthi, N. (2012) “Study of Tool Wear & surface Roughness in end milling of particulate Aluminum MMC with RSM” Journal of Computational and Applied Research In Mechanical Engineering, Vol 2, No. 1, pp. 1-12.