Advance Physics Letter

Experimental studies on the performance of machined surface, and optimization of cutting parameters, tool geometry in machining of metal Al/TiB2, Al/TiC, hybrid–MMCs composites.

[1]Anil Kumar, [2]Onkar Otari, [3]Prem Shankar Sahu

[1]Department of Metallurgical Engineering, NIT, Raipur.
[2]FAG Bearings India Ltd. at Maneja Vadodara, Gujarat.
[3]Department of Mechanical Engineering at BIT, DURG.
Email :- akumar.phd2013.met@nitrr.ac.in

Abstract : Machining of metal matrix composites poses many problems to the manufacturing engineers like high cutting forces and tool wear and cutting tool undergoes severe abrasive wear due to the presence of hard reinforcement. For good machinability it is necessary to have continuous chip in short segment without the use of chip breaker. The chip formation mechanism during machining of Al/TiB2 at low speeds therefore investigated by the quick stop device. The study of chip formation and variation of shear angle for different percentage of reinforcement is carried out.

Key words; aluminum matrix, Al/TiB2, Al/TiC,hybrid – MMCs Chip; shear angle, quick stop device,Taguchi method, ANOVA analysis.

I. INTRODUCTION

In the present work we are using aluminum matrix and titanium boride (TiB2), tungsten carbide(TiC) and hybrid(TiB2+TiC) as a reinforcement. The experimental studies on performances of tungsten carbide tool, machined Surface and optimization of cutting parameters is done for 5% reinforcement of the particles. It is observed that variation in the dimensional accuracy and finish of machined surface on Al/TiB2, Al/TiC and hybrid –MMCs are often function of changes in the processing conditions and compositions of its constituents. These variations clearly reflected in the response variables like surface finish and cutting forces, micro hardness, etc. In this work, study on influence of different cutting parameters on the machinability of Al/TiB2, Al/TiC and hybrid –MMCs of same composition carried out which reflects on the quality of machined surfaces on these composites.Initial research on cutting and grinding of MMCs was started in 1985 and many research papers on machining of aluminum matrix composites have since been published. Almost all the investigations on cutting aluminum matrix composites can be divided into three categories as follows:

(1) Experimental studies on the performance of machined surface, and optimization of cutting parameters, tool geometry and work piece compositions

(2) Empirical and numerical studies related to tool life

Taguchi method is powerful tool for the design of high quality systems. It provides a simpleefficient and systematic approach to optimize design for performance quality and cost. The main trust over Taguchi technique is the use of parameter design which is an engineering method for product or process design that focuses on determining the parameters settings producing the best levels of quality characteristics with minimum variation. The goal of this paper is to predict the surface roughness and cutting force. The levels of the parameters are chosen within the intervals recommended by ASM machining hand book. The L9 orthogonal array is chosen which has 9 rows corresponding to the number of parameter combinations with three levels.

Table 1.1 process parameters

Sr. No.	Composition (% reinforcement)	Cutting Speed (m/min)	Feed (mm/rev)	Depth of cut (mm)
1	5	40	0.05	0.2
2	5	80	0.1	0.6
3	5	120	0.2	1.0

Table 1.2, L9 orthogonal array

Exp No.	Parameter			
	P1	P2	P3	P4
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

II. LITERATURE REVIEW

Uday A. Dabade , S.S. Joshi, done the study ofanalysis of chip formation mechanism in machining of Al/SiC MMCs .According to them Al/SiC composites are known to cause a significant wear of cutting tools. But, with the use of PCD/CBN tools, machining can be continued over longer time duration. The problem associated with the quality of machined surface such as pit marks pull-out still persists. **Uday A. Dabade, DilipDapkekar, Suhas S. Joshi,** In Al/SiCp metal matrix composites, in addition to machine, tool and process-related parameters, a change in composition (size and volume fraction reinforcement) has a influence on machining force components. In the analytical models in the literature, the effect of abrasive reinforcement particles, which affect the coefficient of friction and consequently the friction angle, has not been considered while predicting cutting forces in machining of MMCs. **A. Mannaa, B. Bhattacharayya**, The paper studied the result of an experimental investigation on the machinability of silicon carbide particulate aluminium metal matrix composite during turning using fixed rhombic tools. The influence of machining parameters, e.g. cutting speed, feed and depth of cut on the cutting force and surface finish criteria were investigated during the experimentation. **Uday A. Dabadea, Suhas S. Joshi a, R. Balasubramaniam,** The increasing applications of metal matrix composites (MMCs) for structural and wear resistant components in aerospace, automotive and recreational fields necessitated an in-depth analysis of quality of machined surfaces, which determines the ability of the material to with stand sever conditions of stress, temperature, corrosion, and controls its longevity and reliability. **A. Pramanik, L.C. Zhang_, J.A. Arseculáratne,** This paper done study on a mechanics model for predicting the forces of cutting aluminum-based SiC/Al2O3 particle reinforced MMCs. The force generation mechanism was considered to be due to three factors: (a) the chip formation force, (b) the ploughing force, and (c) the particle fracture force. **S.S. Joshi a, N. Ramakrishnana, P. Ramakrishnan,** This paper is an attempt to understand the machining characteristics of Al/SiCp composite material. Observation of the physical form of chips, a systematic chip breaking pattern was observed. Also, the chip breaking phenomenon was related to the mechanical properties of composites by a chip breaking criterion. **N. Ramakrishnan, P. Ramakrishnan, S.S. Joshi,** conducted a detailed study of fundamental aspects of chip formation during orthogonal machining ofAl/SiCp and observed a systematic chip breaking pattern from the visual observation of the physical form of a chip. Then the chip breaking phenomenon was related to mechanical properties of composites by a chip breaking criteria.

III. METHODOLOGY

In this work the machinability characteristics, like surface finish and cutting forces for different cutting parameters, like speed, feed and depth of cut is studied. All these experiments are done by conducting turning operations on Al/TiB2, Al/TiC and Al/TiB2+TiC(hybrid) of the same composition i. e. 5%.

Table 3.1 process parameters with their values at three levels

Process parameter	Units	Level 1	Level 2	Level 3
Cutting speed	m/min	40	80	120
Feed rate	Mm/rev	0.05	0.1	0.2
Depth of cut	Mm	0.2	0.6	1.0

3.1 LEADWELL TURNING CENTRE

The turning experiments were carried out on the Lead well T5 turning centre. Work pieces of 30 mm in diameter and 100 mm in length were used in the experiments. Coated tungsten carbide tool inserts of geometry CNMG 120408 and grade T9025 manufactured by Tungaloy corporation are used with tool holder (PCNLN 1616 H12). Shows the experimental set up for measuring the cutting forces.

Fig.3.1 The variation of cutting forces on computer screen

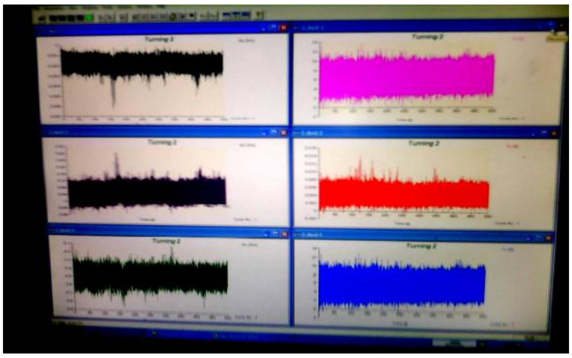

Fig.3.2 The variation of cutting forces on computer screen

EXPERIMENTAL SPECIFICATION

Table 3.2 Experimental Specification

PARAMETER	SPECIFICATION
Machining process	Turning
Work material	Al/TiB$_2$, Al/Tic & Al/Tib$_2$ + TiC composite with 5%, TiB$_2$, TiC&TiB$_2$ +TiC

Tool material	Tungsten carbide
Cutting speed (m/min)	40 to 120
Feed (mm/rev)	0.05 to 0.2
Depth of cut (mm)	0.2 to 0.1

IV. RESULTS

4.1 DESIGN OF EXPERIMENTS

Several tests were conducted using different cutting conditions. All tests were conducted on 5% of Al/TiB2, Al/TiC and Al/TiB2+TiC composite. As the machine is capable of a two axes movement (along the x and z planes), CNC programs could be developed in the T-5 CPU. According to the acceptable ranges of cutting speed and feed rate when cutting aluminium composite in _30 mm & 100 mm long wit5h titanium coated carbide single point cutting tool, three levels of cutting speed 40, 80, & 120(m/min), three levels of feed rate 0.05, 0.1, 0.2 (mm/rev) three levels of depth of cut 0.2, 0.6, 1.0 (mm) were determined. The actual cutting forces were measured in Newton (N) by the cutting force dynamometer.

4.2 ANOVA RESULTS

Cutting parameters plays vital role during any machining process. Hence it becomes important to decide the parameters appropriately. Hence it becomes necessary how much any parameter affects the output parameter. Hence the analysis of variance method was employed to determine the percentage of influence of the spindle speed and feed rate on the thrust force and surface roughness respectively on all the three composite materials. MINITAB 15 was used for the results calculations.

The ANOVA results are based upon three criteria

1. Higher the better.

2. Smaller the better.

3. Nominal the better.

Since in this paper work the aim is to lower the thrust force and the surface roughness values, smaller the better criteria was employed. The percentage influence of each input parameter on the output parameter is indicated in the tables given below for all the three composites. The S/N ratio for each output parameter of the each experiment was calculated S/N ratio= -10 log (yij2)

Where yij - The output parameter.

The input parameters for the ANOVA method are S/N ratio of each factor. The following table shows the S/N ration values for each factor

Table 4.1 S/N Ratio Calculation

C1	C2	C3	C4	C5	C6	C7	C8	C9
40	0.05	0.2	-1.93	-27.95	-5.34	-29.54	-11.07	-32.46
40	0.1	0.6	-4.50	-31.59	-5.93	-33.06	-11.57	-34.48
40	0.2	1.0	-7.49	-37.14	-9.68	-38.06	-13.69	-39.27
80	0.05	0.6	-5.93	-29.54	-7.95	-31.59	-12.38	-31.82
80	0.1	1.0	-3.40	-35.84	-5.52	-35.84	-11.15	-35.26
80	0.2	0.2	-6.40	-28.94	-9.24	-27.95	-13.06	-30.62
120	0.05	1.0	-4.60	-32.04	-4.86	-31.59	-10.68	-33.97
120	0.1	0.2	-9.57	-32.86	-10.50	-32.66	-15.07	-32.86
120	0.1	0.6	-9.15	-31.82	-8.94	-30.88	-12.08	-32.25

Where, C1- Cutting speed

C2- Feed rate

C3- Depth of cut

C4- Surface Roughness Al-TiB2 composite

C5- Cutting force Al-TiB2 composite

C6- Surface Roughness for Al-TiC composite

C7- Cutting force Al-TiC composite

C8- Surface Roughness for hybrid composite

C9- Cutting force for hybrid composite

Results for Al-TiB2 Composite

General Linear Model: C4 versus C1, C2, C3 –

Table 4.2 Analysis of Variance for C4

Factor	Degree of freedom	Sum of squares	Adjusted Sum of Squares	Mean of squares	F value	P value	contribution
C1	2	16.583	16.583	8.291	1.15	0.465	31.60%
C2	2	18.673	18.673	9.337	1.30	0.043	35.57%
C3	2	2.818	2.818	1.407	0.20	0.836	5.37%
Error	2	14.396	14.396	7.198			
total	8	52.469					

Taguchi Analysis: C4 versus C1, C2, C3 -

Table 4.3 Response Table for S/N Ratio (Smaller is better)

Level	C1	C2	C3
1	-12.09	-11.18	-13.82
2	-14.07	-14.44	-15.952
3	-17.37	-17.61	-13.79
Delta	5.28	6.14	2.13
Rank	2	1	3

General Linear Model: C5 versus C1, C2, C3

Table 4.4 Analysis of Variance for C5

factor	Degree of freedom	Sum of squares	Adjusted Sum of squares	Mean of squares	F value	P value	contribution
C1	2	1.259	1.259	0.630	0.16	0.866	1.57%
C2	2	21.283	21.283	10.641	2.61	0.277	28.79
C3	2	43.233	43.233	21.617	5.31	0.158	58.48%
Error	2	8.141	8.141	4.070			
total	8	73.916	73.916				

Taguchi Analysis: C5 versus C1, C2, C3

Table 4.5 Response Table for S/N Ratio (Smaller is better)

Level	C1	C2	C3
1	-30.11	-29.48	-29.50
2	-29.11	-30.47	-29.82
3	-30.17	-30.23	-30.87
Delta	0.26	0.99	1.37
Rank	3	2	1

Results for Al-TiC Composite

General Linear Model: C6 versus C1, C2, C3

Table 4.6 Analysis of Variance for C6

factor	Degree of freedom	Sum of squares	Adjusted Sum of squares	Mean of squares	F value	P value	contribution
C1	2	1.872	1.872	0.936	0.12	0.889	5.05%
C2	2	15.961	15.961	7.981	1.06	0.485	43.07%
C3	2	4.214	4.214	2.107	0.28	0.781	40.48%
Error	2	15.00	15.00	7.503			
total	8	37.053					

Taguchi Analysis: C6 versus C1, C2, C3

Table 4.7 Response Table for S/N Ratio (Smaller is better)

Level	C1	C2	C3
1	-16.568	-15.43	-18.10
2	-17.39	-16.91	-17.50
3	-17.73	-19.35	-16.10
Delta	1.15	3.92	2.0
Rank	3	1	2

General Linear Model: C7 versus C1, C2, C3

Table 4.8 Analysis of Variance for C7

factor	Degree of freedom	Sum of squares	Adjusted Sum of squares	Mean of squares	F value	P value	contribution
C1	2	2.59	2.59	1.29	0.11	0.898	3.37%
C2	2	7.92	7.92	3.96	0.35	0.743	10.32%
C3	2	43.31	43.31	21.65	1.89	0.43	56.48%
Error	2	22.86	22.86	11.43			
total	8	76.68	76.68				

Taguchi Analysis: C7 versus C1, C2, C3

Table 4.9 Response Table for S/N Ratio (Smaller is better)

Level	C1	C2	C3
1	-30.29	-29.80	-29.54
2	-30.00	-30.40	-29.88
3	-30.02	-30.11	-30.96
Delta	0.29	0.61	1.36
Rank	3	2	1

Results for Hybrid Composite

General Linear Model: C8 versus C1, C2, C3

Table 4.10 Analysis of Variance for C8

factor	Degree of freedom	Sum of squares	Adjusted Sum of squares	Mean of squares	F value	P value	contribution
C1	2	0.428	0.428	0.214	0.05	0.955	0.25%
C2	2	4.063	4.063	2.032	0.45	0.695	2.48%
C3	2	2.650	2.650	1.325	0.29	0.774	5.50%
Error	2	9.088	9.088	4.54			
total	8	165.230	165.230				

Taguchi Analysis: C8 versus C1, C2, C3

Table 4.11 Response Table for S/N Ratio (Smaller is better)

Level	C1	C2	C3
1	-21.63	-21.10	-22.25
2	-21.71	-21.92	-21.59
3	-21.93	-22.23	-21.41
Delta	0.30	1.13	0.84
Rank	3	1	2

General Linear Model: C9 versus C1, C2, C3

Table 4.12 Analysis of Variance for C9

factor	Degree of freedom	Sum of squares	Adjusted Sum of squares	Mean of squares	F value	P value	contribution
C1	2	13.907	13.907	6.953	3.09	0.244	27%
C2	2	3.807	3.807	1.904	0.85	0.541	7.39%
C3	2	29.285	29.285	14.643	6.51	0.133	56.86%
Error	2	4.496	4.496	2.248			
total	8	51.496					

Taguchi Analysis: C9 versus C1, C2, C3

Table 4.13 Response Table for S/N Ratio (Smaller is better)

Level	C1	C2	C3
1	-30.95	-30.30	-30.09
2	-30.24	-30.68	-30.33
3	-30.38	-30.59	-31.15
Delta	0.71	0.38	1.06
Rank	2	3	1

V. CONCLUSION

It can be seen from the results that

1. The cutting forces are increasing proportionally with increase in feed rate and depth of cut and decreasing slightly with increasing cutting speed.

2. Increase in feed rate and depth of cut also decreases the surface finish. Whereas increase in cutting speed improves the quality of surface finish. Therefore high speed and low feed rate and depth of cut are recommended for better surface finish.

3. From the ANOVA for 5% Al/TiB2 minimum feed, depth of cut gives the optimum values for the surface roughness. Whereas the minimum values of depth of cut, feed rate and maximum cutting speed for getting optimum cutting force.

4. For 5% Al/TiC minimum depth of cut, speed and feed rare gives optimum value of surface roughness. Whereas the minimum feed rate, depth of cut and maximum speed gives optimum cutting force.

5.For 5% hybrid minimum depth of cut, speed and feed rare gives optimum value of surface roughness. Whereas the minimum feed rate, depth of cut and maximum speed gives optimum cutting force.

REFERENCES

[1] **Uday A. Dabade , S.S. Joshi,** Analysis of chip formation mechanism in machining ofAi/SiC metal matrix composites, journal of materials processing Technology, 2008

[2] **C.C. Tsao, H. Hocheng,** Evaluation of thrust force and surface roughness in drilling composite material using Taguchi analysis and neural. Journal of materials processing technology 203 (2008) 342–348.

[3] **Uday A. Dabade, DilipDapkekar, Suhas S. Joshi,** Modeling of chip tool interface friction to predict cutting force sin machining of Al/SiCp composites. International Journal of Machine Tools & Manufacture 49 (2009) 690–700.

[4] **A. Mannaa, B. Bhattacharayya**, A study on machinability of Al/SiC-MMC. Journal Of Materials Processing Technology 140 (2003) 711–716.

[5] **Uday A. Dabadea, Suhas S. Joshi a, R. Balasubramaniam**, Surface finish and integrity of machined surfaces on Al/SiCp composites. Journal Of Materials Processing Technology 192–193 (2007) 166–174.

[6] **A. Pramanik, L.C. Zhang_, J.A. Arsecularatne,** Prediction of cutting forces in machining of metal matrix composites. International Journal of Machine Tools & Manufacture 46 (2006) 1795–1803.

[7] **Suhas S. Joshi, N. Ramakrishnan,** Analysis of chip breaking during orthogonal machining of Al/SiC composites. Journals Of Materials Processing Technology 88 (1999) 90-96.

[8] **N. Ramakrishnan, P.Ramakrishnan, S.S. Joshi,** Microstructural analysis of chip formation during orthogonal machining of Al/SiCp composites. Trans. ASME, J. Eng. Mater. Technology 123(3), 315-321.

◈◈◈