IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684, p-ISSN: 2320-334X
PP 88-92
www.iosrjournals.org

Optimization of machining parameters in milling of hybrid aluminium metal matrix composite

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ABSTRACT : This paper presents milling machining characteristics of aluminium hybrid metal matrix composite (Al+10%sicp+5%Gr). The milling parameters used here was speed, feed, depth of cut for 3 levels. From the results it has been found that the machinability of aluminium hybrid composite is better over the aluminium composite due to the natural lubricant graphite present in it. The optimized parameters of aluminium hybrid composite was found by taguchi's L_9 orthogonal array experimentation. The significant parameter was found by anova method. Minitab software has been used for taguchi's technique. The fabrication technique adopted was stir casting technique.

Keywords – *Taguchi technique,orthogonal array,tool force,anova,hybrid composite.*

I. INTRODUCTION

Metal matrix composites (MMCs) have become a large leading material in composite materials, and particle reinforced aluminium MMCs have received considerable attention due to their excellent engineering properties. These materials are known as difficult to machine materials, because of the hardness and abrasive nature of reinforcement element like silicon carbide (SiC) particles [1]. The application fields of MMCs include aerospace,defence and automotives [2]. Hybrid MMCs were obtained by reinforcing the matrix alloy with more than one type of reinforcements having different properties [3]. The Al-based hybrid composite, with 20% SiC whiskers and 0, 2%, 5%, 7% SiC nano particles, were fabricated by squeeze casting route [4]. In the view of the growing engineering applications of these composites, a need for detailed and systematic study of their machining characteristics is envisaged. The efficient and economic machining of these materials is required for the desired dimensions and surface finish [5]. Taguchi technique is a powerful tool in experiment design. It provides a simple, efficient and systematic approach for optimization, quality and cost [6]. The methodology is valuable when the design parameters are qualitative and discrete [7]. Optimum machining condition in turning A356/SiC/20p metal matrix composites for minimizing the surface roughness was determined using desirability function approach [8]. UDAY et al [9] presented an elaborative experimentation using Taguchi methods on four Al/SiC composites to analyse the effects of size (15 and 65 µm) and volume fraction (20% and 30%) of the reinforcements in the composites on machining forces and machined surface roughness.

II. EXPERIMENTAL WORK

Experimental work includes the selection of material, fabrication process, machining work and optimization by taguchi's L_9 orthogonal array.

2.1 Material

Al-SiC-Gr Hybrid MMC workpiece having aluminium alloy A356 as the matrix and containing 10% wt. of silicon carbide particles of 25µm mean diameter and 5% wt. of Graphite particles of 25µm mean diameter in the form of cylindrical rods of 110 mm length and 50 mm diameter were manufactured at Compact Vehicles Research Development Organisation (CVRDE) Chennai by stir casting process. The process parameter of stir casting technique are pouring temperature 800-850^{o}C, stirring speed 450 rpm, preheating temperature of silicon carbide 1000^{o}C, preheating temperature of graphite particles 450^{o}C, soaking time of preheated particles 2 Hrs, duration of stirring 15 mts. The melt was poured to the pre heated metallic die of required shape to make the cylindrical rod of 110 mm length and 50 mm diameter. The sample of size 50 mm dia and 25 mm length were then prepared by cutting the rod to the required dimensions. The chemical composition of aluminium alloy A356 is shown in Tab. 1.

Table.1 Chemical composition of aluminium alloy

S.no	Element	Weight percentage
1	Cromium(Cr)	0.05
2	Copper(Cu)	0.20
3	Iron(Fe)	0.15
4	Magnesium(Mg)	0.35
5	Manganese(Mn)	0.10
6	Silicon(Si)	7
7	Titanium(Ti)	0.20
8	Zinc(Zn)	0.10
9	Aluminium(Al)	91.85

a. Machining test

Slot milling operation was selected. The experimental study was carried out in a multi controlled CNC controlled vertical machining center (VMC ARIX 100) capable of working at a speed upto 5000 r.p.m. The selected cutting tool was uncoated tungston carbide inserts for machining MMC material. The levels of machining parameter used in the experiment are given in tab 2. The view of the experimental set-up is shown in fig 2. The surface roughness was measured using a surface analyser of surfcoder 3500 made by kosaka and represented as a surface roughness average (Ra, µm). The results of the surface roughness average values are shown in tab. 4.

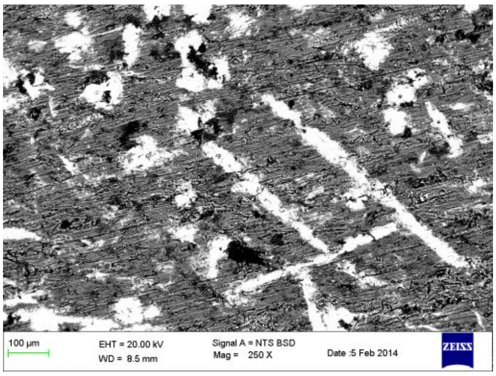

Figure.1 SEM image of hybrid composite

Figure.2 Experimental set up for milling

2.3 Taguchi method

Taguchi methods are statistical methods developed by Genichi Taguchi to improve the quality of manufactured goods and more recently also applied to engineering, biotechnology, marketing and advertising by minimizing the effect of the cause of variation without eliminating the cause. The main trust of taguchi's techniques is the use of parameter design, which is an engineering method for product or process design that focuses on determining the parameter (factor) settings producing the best level of quality characteristic (performance measure) with minimum variation. In particular, it is recommented analyzing metal cutting problems to find the optimal combination of parameters. Further depending on the number of factors, interactions and their level, an orthogonal array is selected by the user. Taguchi has used signal-to-noise (S/N) ratio as the quality characteristic of choice. The S/N ratio characteristics can be divided into three categories given by Eqs. (1) to (3).

- **Nominal is the best characteristics**

$$\frac{S}{N} = 10 \log \frac{\bar{y}}{S_y^2} \qquad (1)$$

- Smaller is the best characteristics

$$\frac{S}{N} = -10 \log \frac{1}{n}\sum_{i=0}^{n} y_i^2 \qquad (2)$$

- Larger is the best characteristics

$$\frac{S}{N} = -\log \frac{1}{n}\sum_{i=0}^{n} \frac{1}{y_i^2} \qquad (3)$$

Table.2 M/Cing parameters and their levels

Level	Machining Parameter		
	Speed (rpm)	Feed rate (mm/min)	DOC (mm)
Level 1	1000	10	0.5
Level 2	1500	15	1.0
Level 3	2000	20	1.5

Table.3 L_9 orthogonal array

Run	A	B	C
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

III. EXP.RESULTS AND DATA ANALYSIS

The plan of the experiment is to find the important factors influencing the machining process to achieve the low surface roughness, thrust force by using the smaller the better characteristics.Tab. 4 illustrates the experimental results. The purpose of analysis of variance is to determine the parameter significantly affecting the machining process. Taguchi recommends analyzing the S/N ratio using conceptual approach that involves graphing the effects and visually identifying the factors that appears to be significant.The experimental results were analysed with analysis of variance (ANOVA), which is used for identifying the factors significantly affecting the performance measures. The results of the ANOVA with the surface roughness and thrust force are shown in Tabs. This analysis was carried out for a significance level of $\alpha = 0.05$ i.e. for a confidence level of 95% Table shows the p-values, that is, the realized significance levels, associated with the F-tests for each source of variation. The sources with a P-value less than 0.05 are considered to have a statistically significant contribution to the performance measures.

3.1 Effect of control parameter on surface roughness

The calculated S/N ratio for three factors on the surface roughness in machining of MMCs for each run is shown in tab.6. The mean value of S/N ratio for each level of three factor is shown in tab.8. Its effect is shown graphically in fig.4. As shown in Tab.8 and Fig.4, speed is a dominant parameter on surface roughness followed by depth of cut and feed. Lower surface roughness is always preferred. In present investigation, when the speed is set at 2000 rpm the surface roughness is minimized. Similarly when the feed and depth of cut are set at 10mm/min and 1.0mm respectively, the surface roughness is minimized. If the depth of cut and feed are set at maximum, the surface roughness is increased. The reason being that the increase in depth of cut and feed increases the heat generation and hence the tool wear, which results in higher surface roughness. Based on the above discussion, the optimum condition for surface roughness: cutting speed (A): 2000rpm, feed (B): 10mm/min, depth of cut (C) : 1.0mm.

Table.4 Exp.results for Al hybrid composite

Run	Speed(A) Rpm	Feed(B) mm/min	Depth of cut (C) mm	Thrust Force(Fz)	Surface Roughness (Ra) (µm)
1	1000	10	0.5	88.71	3.063
2	1000	15	1	125.28	4.218
3	1000	20	1.5	168.87	6.218
4	1500	10	1	109.60	1.731
5	1500	15	1.5	165.28	5.281
6	1500	20	0.5	95.19	3.121
7	2000	10	1.5	140.20	3.419
8	2000	15	0.5	93.28	2.918
9	2000	20	1	115.78	2.112

Table.5 Exp.results for Al composite

Run	Speed(A) rpm	Feed(B) mm/min	Depth of cut (C) Mm	Thrust Force(Fz)	Surface Roughness (Ra) (µm)
1	1000	10	0.5	95.28	4.986
2	1000	15	1	140.28	6.218
3	1000	20	1.5	180.28	8.198
4	1500	10	1	125.89	2.619
5	1500	15	1.5	195.28	8.898
6	1500	20	0.5	105.28	5.616
7	2000	10	1.5	160.28	4.298
8	2000	15	0.5	100.28	3.219
9	2000	20	1	135.19	4.112

a. Effect of control parameter on tool force

The mean value of S/N ratio for each level of three factor is shown in Tab.7. Its effect on tool force is shown graphically in Fig.3. The quality characteristics considered in the investigation is smaller the better

Table.6 S/N ratio for the hybrid composite

Run	Thrust force(Fz) (N)	Surface Roughness(Ra) (µm)
1	-38.65	-13.95
2	-41.95	-15.87
3	-44.55	-18.27
4	-40.79	-08.36
5	-44.36	-18.98
6	-39.57	-14.98
7	-42.93	-12.66
8	-39.39	-10.15
9	-41.27	-12.28

characteristics. From Tab.7 and Fig.3, it can be shown that speed is the dominant parameter in deciding the tool force followed by feed and then depth of cut. As shown in the Fig.3 and Tab.7, the optimum condition for less tool force are : cutting speed(A)-2000rpm, Feed(B)-10mm/min and depth of cut-0.5mm.

Table.7 Response table for S/N ratio

Level	A(rpm)	B(mm/min)	C(mm)
1	-41.82	-40.90	-39.31
2	-41.58	-41.91	-41.34
3	-41.20	-41.80	-43.95
Delta	0.62	1.01	4.64
Rank	3	2	1

Table.8 ANOVA for S/N ratio of thrust force

Source	DF	SS	MS	F	P	
A	2	0.5881	0.2941	45.42	0.022	Significant
B	2	1.8427	0.9214	142.3	0.007	Significant
C	2	32.475	16.237	2507.9	0.000	Significant
Error	2	0.0129	0.0065			
Total	8	34.919				

Table.9 Response table for S/N ratio

Level	A(rpm)	B(mm/min)	C(mm)
1	-16.03	-11.66	-13.03
2	-14.11	-15.00	-12.17
3	-11.70	-15.18	-16.64
Delta	4.33	3.52	4.47
Rank	2	3	1

Table.10 ANOVA for S/N ratio of surface roughness

Source	DF	SS	MS	F	P	
A	2	28.29	14.14	2.13	0.048	Significant
B	2	23.60	11.80	1.78	0.051	
C	2	33.74	16.87	2.55	0.002	Significant
Error	2	13.26	6.62			
Total	8	98.89				

IV. CONCLUSION

- Depth of cut is the most dominant parameter in deciding the tool force and surface roughness when milling aluminium hybrid composite reinforced with silicon carbide and graphite.
- Tool force and surface roughness of the aluminium hybrid composite is reduced when machining due to the presence of solid lubricant graphite.
- The results of the study shows that with a proper selection of machining parameter, it is possible to obtain a better performance when milling hybrid composites with uncoated tungston carbide tool.

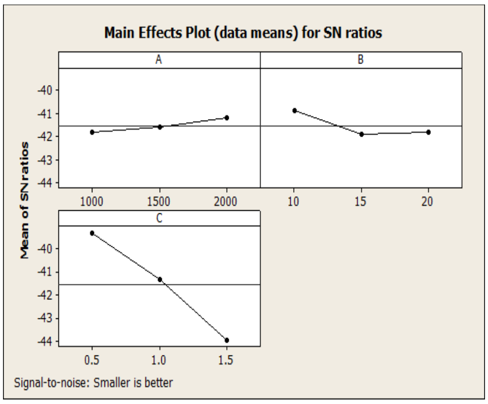

Fig.3 Main effect plot for thrust force

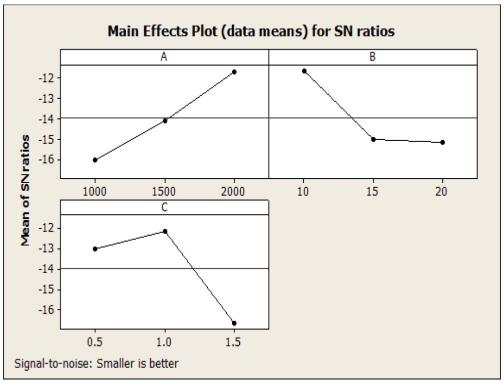

Fig.4 Main effect plot for surface roughness

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