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OPTIMIZATION TECHNIQUES OF TURNING PARAMETERS OF IN-SITU METAL MATRIX COMPOSITE FOR SURFACE ROUGHNESS USING TAGUCHI METHOD

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ABSTRACT

In-situ metal matrix composites have a potential for structural applications because of the presence of fine, small size and uniform distribution of reinforcements. An in-situ synthesized reinforcement particle yields better interface strength between the matrix and reinforcement than the composites fabricated by ex-situ technology. As a result, the mechanical properties, such as strength, stiffness and creep resistance are improved. The objective of the paper is to analyze the influence of machining parameters on surface roughness in turning of in-situ metal matrix composite using taguchi method. The experiments are carried out by using L_{27} (3^{13}) orthogonal array. Analysis of variance (ANOVA) is carried out to identify significant machining parameter affecting the surface roughness. The result indicates that cutting speed is more significant parameter than others. In order to correlate process parameters and measured surface roughness, a mathematical model has been developed by regression analysis.

Keywords: *In-situ composites, surface roughness, L_{27} (3^{13}) orthogonal array*

1. Introduction

Automotive and aircraft industries are seeking high performance materials in order to minimize the weight reduction and improving the fuel economy. Aluminum matrix composite is suitable candidate material with which the improvement has been made not only in decrease in density but also increase the strength and stiffness of the materials. There are many limitations are observed in processing the composite by ex-situ technology. Presence of large size reinforcements, poor wetting and thermodynamic instability leads to a limited improvement in mechanical properties [1]. Fabrication of composite by in-situ route can overcome the limitations. In-situ metal matrix composites are called as multiphase materials where the reinforcing phase is synthesized in a metallic matrix during the composite fabrication. The most important advantage among many is that the reinforcements so formed by the in situ reaction are finer in size and their distribution is more uniform, resulting in better mechanical properties of composites [2].Selecting the optimal cutting parameter for the particular operation is crucial task in order to serve competitiveness and increasing demand of quality product in market [3]. Surface roughness is most critical quality measure for the mechanical components. Taguchi method is usually appreciated for its distribution-free and orthogonal array design and considerable reduction in time. This method is used to determine the important factors affecting operations with simultaneous improvement of quality and cost of manufacturing [4].Many researchers applying taguchi technique to optimize the machining parameters in machining ex-situ aluminum matrix composites. Davim,P.J [5] established a correlation between the cutting velocity, feed and cutting time with tool wear, power and surface roughness in turning of A356/20/Sic_p metal matrix composite. Taguchi technique, orthogonal array and analysis of variance are employed to investigate the cutting characteristics. Manna, A et al.[6] applied taguchi method to optimize the flank wear during turning of Al-20%Sic metal matrix composite. Zhang et al. [7] presented a study of the Taguchi design application to optimize surface quality in a CNC face milling operation. Confirmation tests verified that the Taguchi design was successful in optimizing milling parameters for surface roughness. Shetty et al. [8] reported a taguchi based experimental investigation to optimize the cutting force and cutting temperature in turning of Al6061/15/Sic composite. Navensait et al.[9] used taguchi method for predicting the surface roughness, cutting force; flank wear and crater wear as well as finding the optimal process parameter in machining of aluminum - glass fiber reinforced composite. Palanikumar,K and Karthikeyan,R [10] studied the influence of machining parameters on the surface finish obtained in turning of LM25 Al/SiC particulate composites. The experiments

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are conducted based on Taguchi's experimental design technique. The results and discussion shows that the developed model can be effectively used to predict the surface roughness on the machining of Al/SiC-MMC composites with 95% confidence intervals. However there is no work addresses the optimization of the machining parameters for in-situ composites. Therefore an attempt has been made to study the effect of machining parameters on the surface roughness in machining of Al-ZrB_2 in-situ metal matrix composite. Optimum machining conditions for minimizing the surface roughness is determined by using taguchi method.

2. Experimental Work

In-situ Al-ZrB_2 metal matrix composite specimens having aluminum alloy 6061 as matrix and containing 6 % volume of ZrB_2 particles. The specimen is fabricated by flex assisted synthesis by reacting KBF_4 and K_2ZrF_6 salts. Fine, oxide free and uniform distributions of reinforcements are observed (Figure1 and 2) in material characterization [11]. Turn master -35 lathe (Kirloskar make) is used to carry out machining test (Figure 3.) and surf test 210(Mitutoya, Japan) instrument is used to measure the surface roughness. The specification of insert and tool holder is given in table1 The turning parameters namely cutting speed, feed rate and depth of cut each at three levels are considered in this work and the details are presented in the table 2. L_{27} (3^{13}) orthogonal array is selected to carry out the experimentation.

Table 1: Experimental conditions

Experimental conditions	
Cutting tool	Uncoated tungsten carbide
Cutting tool specification	SNMG120408 MTTT5100
Tool holder specification	PSBNR-2525M12
Clearance angle (o)	7
Cutting edge angle(o)	75
Nose radius (mm)	0.8
Reinforcement ratio (wt %)	6
Cutting condition	Dry

There are three types of quality characteristics are available in taguchi method namely smaller-better, nominal -better and larger- better .This research work is aimed to produce the minimum surface roughness of the machined components. Therefore a smaller-better characteristic is applied in this study. The surface roughness value for each experiment is evaluated as per L_{27} (3^{13}) orthogonal array and reported in table -3.

Table 2: Factors and levels of experimental work

Factor Notation	Factor	1	2	3
A	Cutting speed(m/min)	100	125	150
B	Feed rate(mm/rev)	0.05	0.1	0.2
C	Depth of cut (mm)	0.5	1.0	1.5

Table 3: L_{27} (3^{13}) orthogonal array table

Trail No.	Levels			Surface roughnes s(µm)
	A	B	C	
1	1	1	1	1.6
2	1	1	2	1.73
3	1	1	3	1.85
4	1	2	1	1.89
5	1	2	2	1.92
6	1	2	3	1.98
7	1	3	1	1.99
8	1	3	2	1.96
9	1	3	3	2.2
10	2	1	1	1.53
11	2	1	2	1.62
12	2	1	3	1.63
13	2	2	1	1.66
14	2	2	2	1.63
15	2	2	3	1.59
16	2	3	1	1.89
17	2	3	2	1.73
18	2	3	3	1.85
19	3	1	1	1.51
20	3	1	2	1.54
21	3	1	3	1.69
22	3	2	1	1.79
23	3	2	2	1.64
24	3	2	3	1.76
25	3	3	1	1.77
26	3	3	2	1.58
27	3	3	3	1.86

3. Analysis of Results

Generally lowest surface roughness value is desired for setting optimal parameters. Table 3 shows that trail number 19 has lowest value of surface roughness. Therefore trail number 19 is optimal machining parameters among the 27 trails, which yields minimum surface roughness in turning of composite. Response table (Table 4) and graph (Figure 1) for given experiment layout is generated by using Minitab 14 package. Response table for surface roughness is generated by grouping the responses by factor level for each column in the orthogonal array and taking average of them. Table 4 shows the difference between maximum and minimum value is more for cutting speed followed by cutting feed rate and depth of cut. These values indicate that cutting speed has strongest effect on multi-performance characteristics then other parameters. Response graph as shown in Fig.2 reveals that A_3, B_1 and C_1 have lowest response values. Therefore optimal level of parameters in turning of Al6061-ZrB_2 in-situ metal matrix composite for attaining good surface finish can be given as A_3, B_1 and C_1.

Table 4: response table for S/N ratio for surface roughness and significant interaction

Parameters Level	A Speed	B feed	C DOC	AB Speed-Feed	BC Feed-DOC	AC Speed-DOC
1	-5.67	-7.19	-6.09	-6.44	-4.33	-6.48
2	-8.01	-5.91	-6.74	-7.46	-5.08	-6.16
3	-5.65	-6.22	-6.50	-6.43	-5.49	-6.97
Delta	2.36	1.28	0.65	1.03	1.16	0.81
Rank	1	2	6	4	3	5

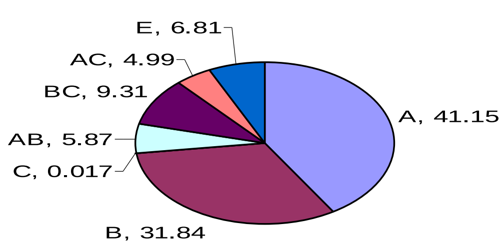

Fig. 1 Percentage contribution of factors and their interactions

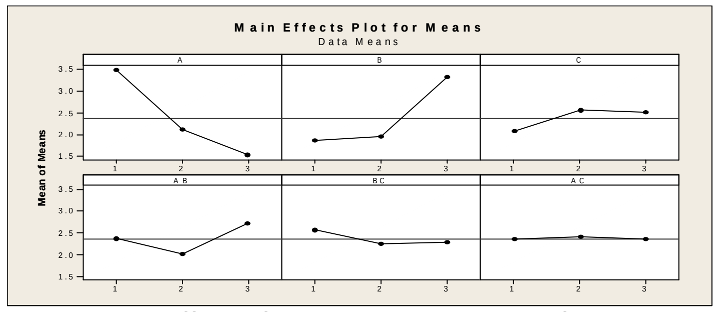

Fig. 2 Main effects of plot and interaction plot for average response (surface roughness)

4. Analysis of Variance

Analysis of variance is performed to determine the level of significance of influencing factors by using Minitab-14 package and tabulated in Table 5. It is observed that the cutting speed (41.15%) is most significant factor followed by feed rate (31.84%) and Feed-depth of cut (9.31%). It can be observed from tables 4 and 5 the order of importance (A > B > BC > AB > AC > C) for the factors are in same sequence, which reveals the accuracy of the Taguchi method.

Table 5: Result of ANOVA

Factor notation	Control factor	DOF	Seq SS	Adj SS	Adj MS	F-Test	Percentage of contribution
A	Speed	2	0.305	0.305	0.152	42.36	41.15
B	Feed	2	0.040	0.040	0.020	5.69	31.84
C	DOC	2	0.0217	0.0217	0.0108	3.02	0.017
AB	Speed -Feed	2	0.0435	0.0435	0.0217	6.04	5.87
BC	Feed –DOC	2	0.069	0.069	0.034	9.69	9.31
AC	Speed -DOC	2	0.037	0.037	0.018	5.17	4.99
Error		14	0.0504	0.0504	0.025	0.03	6.81

5. Correlation

Correlation between the cutting speed, feed rate and depth of cut and measured value of surface roughness was obtained by multiple liner regression from Minitab14 package. At the optimal setting condition the surface roughness equation obtained was as follows.

$$Ra= 1.45+ 0.216A-0.141B-0.032 C+ 0.077AB+0.726BC+0.048AC \quad (1)$$

6. Confirmative Test

Confirmative test was conducted to verify the improvement of performance characteristics at the optimal levels of selected turning parameters. The optimum machining parameter for the turning operation was set, and two trials were conducted. Table 6 shows that 2.2 % error is observed between the predicted value (1.481 μm) and experimental value (1.515 μm) of the optimum parameters. There is a 5.3 % improvement in surface roughness is achieved by setting optimal parameter (1.515 μm) when compared to initial machining parameters(1.6 μm). Therefore Eq. 1 correlates the evaluation surface roughness with a reasonable degree of approximation.

Table 6 : Result of confirmative test

Level	Initial machining parameters	Optimal machining parameters	
		Prediction (Equation1)	Experiment (Average value of trail 1 &2)
Setting level	A_1 B_1 C_1	A_3 B_1 C_1	A_3 B_1 C_1
Surface roughness	1.6 μm	1.481 μm	1.515 μm

7. Conclusion

The optimal level of machining parameters to obtain good surface finish in turning of Al-6061-6% ZrB_2 in-situ metal matrix composite are A3(cutting speed of 150 m/min),B_1 (Feed rate of 0.05 mm/rev) and C_1(Depth of cut of 0.5mm). The difference between maximum and minimum value of surface roughness obtained from response table shows that the cutting speed has greater influence of surface roughness. Analysis of variance also confirmed that cutting speed has significant influence on surface roughness with 41.15 % contribution followed by feed rate 31.84 and the interaction feed rate-depth of cut 9.31 %. It is observed form the confirmation experiment that there is a good agreement between the estimated value and experimental value of the surface roughness. Thus linear regression model may employ successfully for designing process parameters in turning of Al-6061-6% ZrB_2 in-situ metal matrix composite.

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