FORECASTING OF OPTIMUM TURNING PARAMETER ON SURFACE ROUGHNESS IN TURNING OF AL-AL_2O_3 METAL MATRIX COMPOSITE

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Abstract

The objective of this research work is to apply taguchi method to investigate the effects of turning parameters such as cutting speed, depth of cut and feed rate on surface roughness, in Turning of Al-Al_2O_3 MMC using TiC coated HSS cutting tool. The Signal–to- Noise (S/N) ratio, the analysis of variance (ANOVA), and regression analysis are used to analyze the effect of drilling parameters on the quality characteristic of machined work piece. A series of experiments are performed based on L_9 orthogonal array. The experimental results obtained are analyzed using MINITAB software package. Linear regression equations are used to develop a statistical model with an objective to establish a correlation between the selected drilling parameters with the quality characteristics of the machined work piece.

Keywords*:* Turning, Al-Al_2O_3 MMC, Taguchi method, Surface finish, Tool wear, Surface Roughness, Regression analysis, (S/N) ratio, ANOVA.

1. Introduction

Metal matrix composites (MMC) are widely used composite materials in aerospace, automotive, electronics and medical industries. They have outstanding properties like high strength, low weight, high modules, low ductility, high wear resistance, high thermal conductivity and low thermal expansion. These desired properties are mainly manipulated by the matrix, the reinforcement element and the interface [1]. As the matrix element, aluminium, titanium and magnesium alloy are used, while the popular reinforcements are silicon carbide (SiC) and alumina (Al_2O_3).

Aluminium-based SiC particle reinforced MMC materials have become useful engineering materials due to their properties such as low weight, heat-resistant, wear-resistant and low cost [2]. However, the final conversion of these composites in to engineering products is always associated with machining, either by turning or by milling. A continuing problem with MMCs is that they are difficult to machine, due to the hardness and abrasive nature of the reinforcing particles [3]. The particles used in the MMCs are harder than most of the cutting tool materials. Most of the researchers reported diamond is the most preferred tool material for machining MMCs [4].

Most of the research on machining MMCs is concentrated mainly on the study of cutting tool wear and wear mechanism [5]. It has been investigated the performance of polycrystalline diamond in machining MMCs which containing aluminum oxide fiber reinforcement. They compared the tool life of cemented carbide with PCD and concluded that sub-surface damage is greater with cemented carbide than that of PCD tools. It has been studied the performance of different PCD tools grain size. He reported that, PCD tools with a grain size of 25μm are better withstand of abrasion wear than tools with grain size 10 μm. It is also reported that further increases in the grain size do not have any influence on the tool life but it cause significant deterioration in the surface roughness [6].

It has been investigated that the taguchi optimization methodologies to optimize the cutting parameter in turning of age hardened AlSiC - MMC with CBN cutting tool. Authors analysed the data using ANOVA with the help of commercial software package Minitab -15 [7].

In the view of above machining problems, the main objective of the present work is to investigate the influence of different cutting parameters on surface finish. The taguchi L_9 orthogonal array is utilized for experimental planning for turning of Al-Al_2O_3 –MMC. The results are analyzed to achieve optimal surface roughness. Analysis of variance is also performed to investigate the most influencing parameters on the surface finish.

2. Experimental work

In this study, aluminum reinforced with Al_2O_3 of particle of size 25 μm with 10% volume fractions manufactured through stir casting process is used as MMC for experimental work. The turning tests are performed on lathe machine under dry condition. In order to perform the experiments, the metal matrix composite is cut into 20 mm diameter and 150 mm length. The standard HSS cutting tool coated with TiC are used.

2.1 Plan of experiment

Three factors and three levels considered in this study are mentioned in Table 1. The experiments are performed using L_9 orthogonal array in order to reduce time and cost .The response values obtained are shown in Table 2. Regression analysis is employed to analyze the effect of the drilling parameters on surface roughness. The settings of drilling parameters were determined by using taguchi design method on the basis of L_9 orthogonal array.

Table 1. Process parameter and their Levels

Parameter	Level-1	Level-2	Level-3
Cutting Speed	188	296	404
Feed	0.10	0.16	0.22
Depth of Cut	0.5	0.6	0.7

3. Design and Analysis of Cutting Parameters

The results of the experiments were studied using the (S/N) ratio and ANOVA analyses. Based on the results of the S/N ratio and ANOVA analyses, optimal cutting parameters for surface roughness were obtained.

Table 2. L_9 orthogonal array and the desired parameter values

Sl. No	Speed (R.P.M)	Feed (mm/rev)	DOC (mmm)	Ra (μm)
1	188	0.10	0.5	4.88
2	188	0.16	0.6	4.98
3	188	0.22	0.7	4.94
4	296	0.10	0.6	5.21
5	296	0.16	0.7	5.38
6	296	0.22	0.5	5.25
7	404	0.10	0.7	5.44
8	404	0.16	0.5	5.69
9	404	0.22	0.6	5.78

3.1 Analysis of the signal to noise (S/N) ratio

In the Taguchi approach, the term ‘signal’ represents the desired value (mean) for the output characteristics and the term ‘noise’ represents the undesirable value (S.D) for the output characteristics. Therefore, the S/N ratio is the ratio of the mean to the S.D. Taguchi uses the S/N ratio to measure the quality characteristics deriving from the desired value [11]. The S/N ratio η is defined as given in equation 1.

$$\eta = -10 \times \log_{10}(\mathrm{MSD}) \qquad (1)$$

Smaller-the-better

It is used when the occurrences of some undesirable product characteristics is to be minimized. It is given by equation 2.

$$\eta = -10 \times \log_{10}\left[\frac{\sum y_i^2}{N}\right] \qquad (2)$$

Here, η is the resultant S/N ratio; N is the number of observations on the particular product, and y is the surface roughness. The factor 10 ensures that this ratio measures the inverse of bad quality; the more flaws in the paint, the greater is the sum of the sum of squared number of flaws, and the smaller (i.e. , more negative) the S/N ratio. Thus, maximizing this ratio will increase quality. It is better suitable for quantity like surface roughness [5].

Table 3. S/N Response Table for Surface roughness Mean S/N ratio (dB)

Symbol	Cutting Parameters	Level-1	Level-2	Level-3	Max-Min.
A	Cutting Speed	188	296	404	188
B	Feed	0.10	0.16	0.22	0.10
C	DOC	0.5	0.6	0.7	0.5

3.2 Analysis of the variance

Analysis of variance (ANOVA) is done to determine the parameter which is most affecting the result of experiments i.e. which parameter significantly affects the surface roughness. This is achieved by separating total variability of the S/N ratio, which is measured by the sum of squared deviation (SS_T) from total mean S/N ratio into contribution by each design parameters and the error [5].

First the total sum of squares (SS_T) is calculated by using equation 3.

$$SS_T = \sum_{i=1}^{n} (n_i - m)^2 \qquad (3)$$

Where n is the no. of experiments in the orthogonal array and n_i is the mean S/N ratio for the i-th experiments.

The SS_j and SS_e are calculated using equation 4 and 5.

$$SS_j = \sum_{j=1}^{l} \left(n_j - m\right)^2 \qquad (4)$$

$$SS_T = \sum_{j=1}^{n_P} SS_j + SS_e \qquad (5)$$

Total sum of squares (SS_T) is decomposed in to two sources, the sum of squared deviation SS_J due to each design parameters and sum of squared error SS_e Percentage contribution (p_j) and F-value of each of the parameter is calculated using equation 6.

$$p_j = \frac{SS_j}{SS_e} \qquad (6)$$

$$F_j = \frac{MS_j}{MS_e} \qquad (7)$$

F-test is used to identify the parameter that has significant effect on quality characteristic. The F-value of each design parameter is a ratio of mean squared deviations to the mean squared error. If the value of F is more than 4 then it means change of design parameters have a significant effect on quality characteristics.

From ANOVA table for surface roughness it is observed that depth of cut and drill point angle are the significant parameters for the affecting the surface roughness. The optimal cutting parameters for surface roughness are the cutting speed at level 3, depth of cut at level 3 and drill point angle 3.

Table 4. Results of the Analysis of variance for Surface Roughness

Symbol	Cutting Parameter	DOF	Sum of Squares	Mean Square	F	P	Contribution (%)
A	Cutting Speed	2	0.7421	0.3710	26.84	0.001	93
B	Feed	2	0.052	0.026	0.03	0.972	1
C	DOC	2	0.008	0.004	1.94	0.340	6
Error		2	0.5603	0.2788			
Total		8	1.3624				

4. Result and Discussion

4.1 Main effects plots

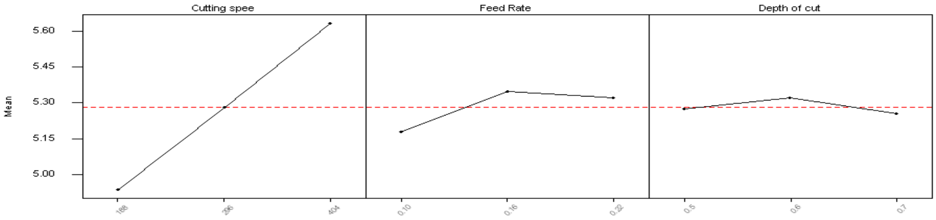

Figure.1 Effect of process parameter on Surface roughness

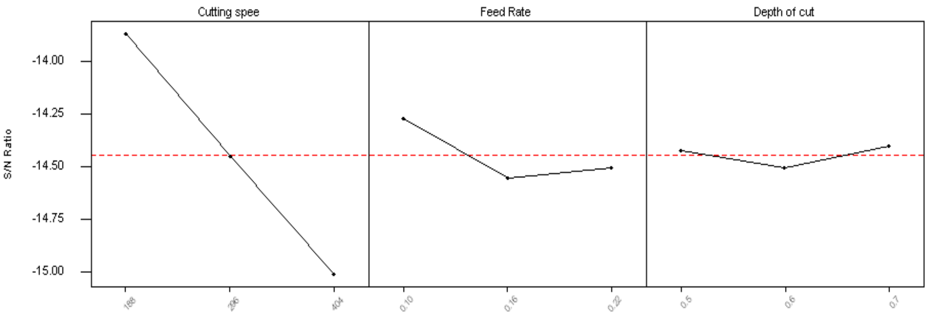

Figure.2 Effect of Signal to noise ratio on Surface roughness

Figure 1 and 2 displays the main effect plots for surface roughness. It can be seen that the Speed, feed and depth of cut are significant parameters affecting surface roughness. It has been observed that surface roughness increases with increase in speed. This is due to fact that at higher cutting speeds, cutting forces and tendency towards built-up edge formation weakens due to increase in temperature and consequent decrease of frictional stress at the rake. The surface roughness in the case of feed rate increases and then decreases. The surface roughness has been found to be increased with increasing the depth of cut then decreases.

4.2 Modeling of Surface Roughness

The cutting speed, depth of cut and feed are considered in the development of mathematical models for surface roughness. Model has been obtained by analyzing the data presented in Table 2 and is given below as Eq. (8). The correlations between the considered turning parameters for turning conditions on Al-Al_2O_3 are obtained by linear regression. The linear polynomial models are developed using commercially available Minitab 13 software for various turning parameters. The improved model after neglecting the terms, which have insignificant effect on the surfaces roughness, is obtained as

Ra = 4.18 +0.00326 Speed + 1.22 Feed Rate – 0.1 Depth of Cut ………………….. (8)

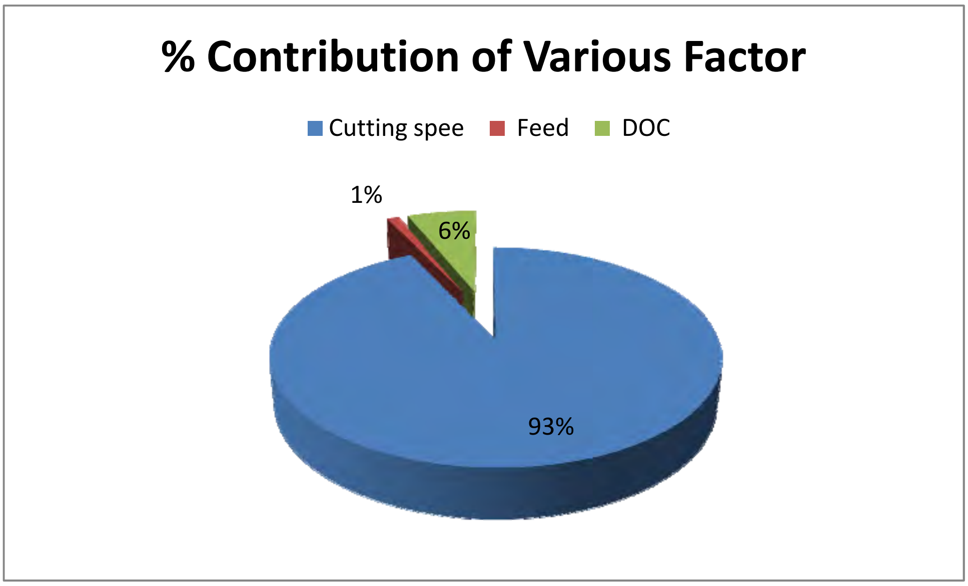

Figure.3 Percentage contributions of factors

ANOVA for the response surface given by Eq.8 is presented in Table 4. It is clear from the *F*-test that the model is adequate at 99% confidence level as the *F*-value of model is higher than the tabulated *F*-value. The significant main effects of factors affecting the surface roughness is the cutting speed with the contributions of 93%, whereas the depth of cut and feed are insignificant contributing only 6% and 1% respectively.

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