Experimental Analysis and Optimization of Hot Machining Process Parameter Process by Employing Taguchi Method

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Abstract: Al/SiCp Metal Matrix Composites (MMCs) are the new class of materials and are rapidly replacing conventional materials in various applications industrial and aerospace applications. These materials are generally regarded as extremely difficult to machine, because of the abrasive characteristics of the reinforced particulates. It has poor machinability such as excessive tool wear and fracturing of the reinforcement particles on machined surface. In our work we presented the application of Taguchi method to figure out which process parameters like Cutting Speed (m/min), Feed (mm/rev), Depth of Cut (mm) will produce much impact on the Surface Roughness. Hence, an attempt is made to improve the machinability of Al/SiCp MMCs and surface quality by hot machining. Optimal values of process parameter with regard to desired performance characteristic are received by Taguchi design of experiment. Multiple regression modelling was performed to predict the surface roughness by using machining parameter. Comparison between experimental values and predict values is carried out.

Keywords: Cutting speed, Optimization, Surface roughness, Taguchi technique.

I. Introduction

The topic for the paper writing is the Experimental Analysis and optimization of hot machining process parameter by employing Taguchi Method. The focus on this paper is to obtain an optimum process parameter consider as cutting speed, feed rate and depth of cut which provides the optimum value of surface finish. The experimentation plan was created using Taguchi's L9 Orthogonal Array (OA) and Minitab 17 statistical software is employed. Optimal values of process parameter with regard to desired performance characteristic are received by Taguchi design of experiment [1-4].

II. Methodology

The size of specimen is as per ASTM standards. The experimental studies were carried out on a MTAB CNC turning centre. All the experiments were conducted under resistance preheating conditions. In the present work nine no of experiment (L9) were conducted based on the Orthogonal Array (OA) of Taguchi method [5-6]. The single response optimization of the hot machining parameters Surface roughness has been performed for machining of Al/SiCp MMCs. All the values of SR are noted down for analysis in each run [7]. Our consideration for analyzing Surface Roughness is smaller is better [8].

A. Taguchi Method

While conducting an experiment, we have to perform enormous number of experimental works. Upon increasing number of process parameters that problem is solved with the help of Taguchi method, in which by using Design of Experiment (DOE) an unusual design of OA we convert entire parameter space in very less number of experiment run subject to % accuracy. Among them all saving of work in accompanying experiments, saving experimental time, lowering the cost is the greatest advantage of this method [8-10]. The steps followed for Taguchi optimization in this work are presented as:

1. Smaller the better: $SN_S = -10\log\left(\frac{1}{n}\sum_{i=1}^{n} Y_i^2\right)$ (1)
2. Nominal the best: $SN_T = 10\log(Y^2/S^2)$ (2)
3. Larger the better: $SN_L = -10\log\left(\frac{1}{n}\sum_{i=1}^{n} 1/Y_i^2\right)$ (3)

Where *n* is the number of observations and y is the observed data.

III. Experimentation and Analysis

Table I: Machining Process Parameters

Factor		Symbol	Level 1	Level 2	Level 3
A	Cutting Speed (m/min)	CS	35	55	75
B	Feed (mm/rev)	F	0.12	0.16	0.21
C	Depth of Cut (mm)	DOC	0.5	1.6	2.7

TABLE II: EXPERIMENTAL RESULTS FOR L9 ORTHOGONAL ARRAY & SN RATIO FOR SURFACE ROUGHNESS

Trial No.	Experimental Data According to Taguchi L9 Orthogonal Array Design				S/N Ratio for Response from Minitab
	Machining Parameters			Responses Parameter	
	CS (m/min)	F (mm/rev)	DOC (mm)	SR (µm)	
1	35	0.12	0.5	1.7500	-4.86076
2	35	0.16	1.6	1.1100	-0.90646
3	35	0.21	2.7	0.9500	0.44553
4	55	0.12	1.6	0.8000	1.93820
5	55	0.16	2.7	1.6000	-4.08240
6	55	0.21	0.5	1.1800	-1.43764
7	75	0.12	2.7	1.2000	-1.58362
8	75	0.16	0.5	1.3200	-2.41148
9	75	0.21	1.6	1.8200	-5.10545

S/N ratio of Surface roughness is calculated by considering Smaller is better.

Experimentation and analysis

In MINITAB 17 software Taguchi methodology is used for analysis and optimization.

A. Taguchi Analysis: SR versus CS, FR, DOC

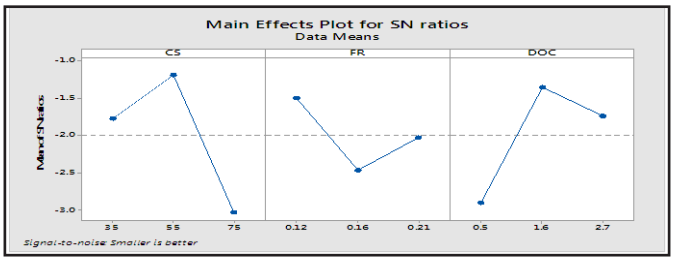

Fig. 1: Main Effect Plot for SN Ratios (SR)

TABLE III: RESPONSE TABLE FOR SN RATIOS (LB)

Level	CS	F	DOC
1	-1.774	-1.502	-2.903
2	-1.194	-2.467	-1.358
3	-3.034	-2.033	-1.74
Delta	1.840	0.965	1.545
Rank	1	2	3

From the main effect plot for SN ratios, parameter combination recommended for the lesser Surface Roughness is Cutting Speed (m/min), 55 m/min, Feed (mm/rev), 0.16 mm/rev, Depth of Cut (mm), 1.6 mm & From the Taguchi analysis it was found that the Cutting Speed is the most important significant factor which affects the Surface roughness followed by Feed and Depth of Cut respectively.

B. Regression Analysis

Regression analysis with help of Minitab 17.0 software is used it is able to calculate predict values for responses in comparison between experimental values and predicted values. Regression analysis is used to investigate and model the relationship between a response variable and one or more predictors. Different values are calculated and written in tabular form having different dimensions.

TABLE IV: TO CALCULATE ERROR BETWEEN EXPERIMENTAL AND PREDICTED VALUE

S. No.	Cutting Speed (m/min)	Feed Rate (mm/rev)	DOC (mm)	Surface Roughness Ra	Predict Ra	Error
1	35	0.12	0.5	1.75	1.27	0.477077
2	35	0.16	1.6	1.11	1.21	-0.104071
3	35	0.21	2.7	0.95	1.16	-0.211339
4	55	0.12	1.6	0.80	1.27	-0.474590
5	55	0.16	2.7	1.60	1.22	0.384262
6	55	0.21	0.5	1.18	1.41	-0.233005
7	75	0.12	2.7	1.20	1.28	-0.076257
8	75	0.16	0.5	1.32	1.47	-0.147404
9	75	0.21	1.6	1.80	1.41	0.385328
Average Error = -0.03						

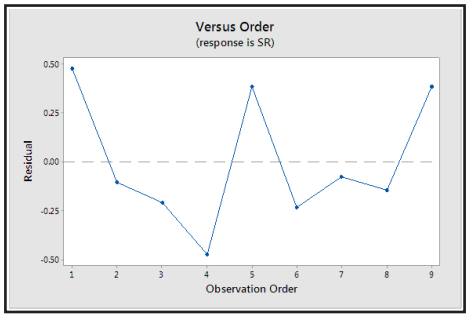

Fig. 2: Residuals Vs Order for SR

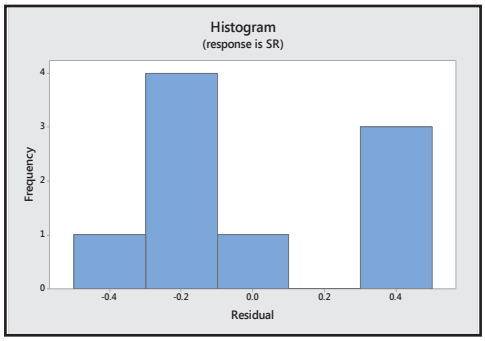

Fig. 3: Residual Histogram for SR

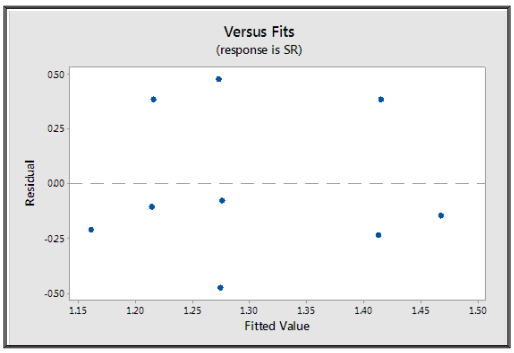

Fig. 4: Residuals Vs Fits for SR

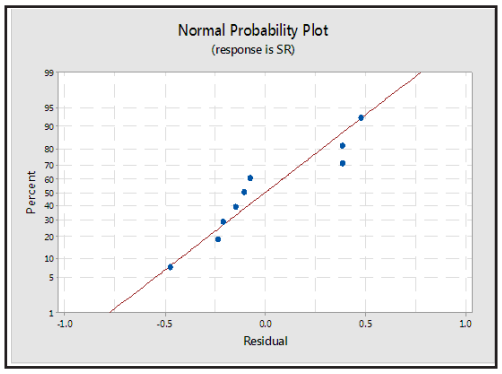

Fig. 5: Normplot of Residuals for SR

IV. Conclusion

This paper illustrates the application of the parameter design (Taguchi method) in the optimization of machining operation. The following observation can be drawn based on the above experimental results of this study:

- In this particular work the effect of machining parameters speed, feed, depth of cut, are analysed on surface roughness for machining operation. The results reveal that the primary factor affecting the surface roughness is cutting speed subsequently followed by feed rate and depth of cut.
- For surface roughness, our observation is based on smaller is better for s/n ratio. Cutting speed has greater effect than feed and depth of cut, our observation is based on smaller is better for s/n ratio.
- The lowest surface roughness (Ra) of 0.80 µm was achieved corresponding to: F: 0.12 mm/rev, CS: 55m/min. and DOC: 1.6 mm.
- From the graph of S-N ratio it can be observed that optimal value of surface finish is obtained at second level of cutting speed, first level of feed rate and second level of depth of cut.
- Further, Regression Analyses (RA) technique is used to study the effect of these parameters and their interaction on surface roughness. An empirical equation is formed by using Regression Analyses (RA) in MINITAB software to predict the surface roughness and Experiment value and predict value of surface roughness both values are minimum error 0.03 values.
- Outlining all results I can state that if there are used correct cutting parameters, cutting material and geometry of a tool then machining of Al/SiCp Metal Matrix Composites is economical and effective.

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