Surface Roughness Optimization Of Metal Matrix Composite Using Taguchi Technique

M.Sureshkumar[a] ,M.Mohana priya[a] , C SathishKumar[a] , Dr.V.baskaran[b]
[a]Assistant Professor,
Department of Mechanical Engineering,
Bannari Amman Institute of Technology, Sathyamangalam.Erode.

[b] Professor,
Department of Mechanical Engineering,
Bannari Amman Institute of Technology, Sathyamangalam.Erode.

Abstract

This paper presents the study on Taguchi's optimization methodology, which is applied to optimize cutting parameters in turning of Al 6063 with 10% Sic.Particle size of Sic metal matrix composites are 45 µm. Analysis of variance (ANOVA) is used to study the effect of process parameters on the machining process. This procedure eliminates the need for repeated experiments, time and conserves the material by the conventional procedure. The turning parameters evaluated are speed, feed, depth of cut which results in an optimal value of Surface Roughness. The measured results were collected and analyzed with the help of the commercial software package MINITAB16. As well, an orthogonal array, signal-to-noise ratio is employed to analyze the influence of these parameters. In our study, an attempt has been made to generate a model to predict Surface Roughness using Regression Technique. Also an attempt has been made to optimize the process parameters using Taguchi Technique. S/N ratio and ANOVA analysis were also performed to obtain significant factors influencing Surface Roughness.

Keywords: Turning operation, Surface Roughness, Mathematical Model, ANOVA, Taguchi Technique

1. Introduction

Metal matrix composites (MMCs) derive their excellent mechanical properties from the combination of a hard reinforcement phase such as silicon carbide (SiC) and a ductile matrix material such as aluminum or magnesium. While current applications for this class of materials are primarily limited to aerospace and automotive applications, their development continues with resulting new products such as high voltage power transmission lines and heat sinks for electronic components (Evans et al, 2003).

From past so many years it has been recognized that conditions during machining such as cutting speed, Feed and Depth of Cut (DOC) should be selected to optimize the economics of machining operations. Manufacturing industries in developing countries suffer from a major drawback of not running the machine at their optimal operating conditions. Machining industries are dependent on the experience and skills of the machine tool operators for optimal selection of cutting conditions. In machining industries the practice of using hand book based conservative cutting conditions are in progress at the process planning level. The disadvantage of this unscientific practice is the decrease in productivity due to sub optimal use of machining capability. The literature survey has revealed that several researchers attempted to calculate the optimal cutting conditions in turning operations. Armarego and Brown used the concept of maxima / minima of differential calculus to optimize machining variable in turning operation [1]. Brewer and Rueda have developed different monograms which assist in the selection of optimum conditions [2]. Some of the other techniques which have been used to optimize the machining parameters include goal programming

[3] and geometrical programming [4]. Now a day's more attention is given to accuracy and Surface Roughness of the product in the industries. Surface roughness is the most important criteria in determining the machinability of the material. Surface Roughness and dimensional accuracy are the major factors needed to predict the machining performances of any machining operation [5]. Most of the Surface Roughness prediction models are empirical and they are generally based on experiments conducted in the laboratory. Also it is difficult in practice, to keep all factors under control as required to obtain the reproducible results [6].

Optimization of machining parameters increases the utility for machining economics and also increases the product quality to greater extent [7].Taguchi has proposed off line for quality improvement in place of an attempt to inspect quality in the product on the product line. He observed that no amount of an inspection can put quality back into the product but it merely treats a symptom. Taguchi has recommended three stage processes to achieve the desirable product quality by design. They are 1). System Design 2). Parameter Design and 3). Tolerance Design. System design helps to identify the working levels of the design parameters. Parameter design determines the parameter levels that H.M.Somashekara et al.

The optimal condition is selected so that influence of noise factors (uncontrollable factors) causes minimum variation to study performances. The orthogonal arrays, variance and signal to noise analysis are the essential tools of parameter design. Tolerance design is used to fine tune the results of parameter design by tightening the tolerance of the parameter with the significant influence on the product.

2. Taguchi technique

Genichi Taguchi is a Japanese Engineer who has been active in the improvement of Japans industrial product and processes since the late 1940s. He has developed both philosophy and methodology for the process or product quality improvement that depends mainly on statistical concepts and tools, especially statistically designed experiments. Many Japanese firms achieved great success by applying his methods. Taguchi has received some of the Japan's most prestigious awards for quality achievement, including the Deming Prize [8]. During the year 1986, he received the most prestigious award from the International Technology Institute- The W.F.Rockwell Medal for excellence in Technology. His major contribution is that he has combined engineering and statistical techniques to achieve rapid improvements in reducing the cost and increasing the quality level by optimizing product design and manufacturing processes. During 1983, Taguchi associated with top companies and institutes of USA (Ford motor company, XEROX, AT&T, Bell laboratories etc), Taguchi techniques are called as Radial approach to quality, experimental design and engineering [9].

Taguchi technique refers to the Parameter Design, Tolerance Design, Quality Loss Function, Design of Experiments using Orthogonal Arrays and Methodology applied to evaluate measuring systems [8]. Pignatiello [10] has identified two different aspects of Taguchi technique 1). The strategy of Taguchi. 2). Tactics of Taguchi. Taguchi strategy is the conceptual frame work for planning a process or product design experiment. Taguchi tactics refer to the collection of specific techniques used by Taguchi. Taguchi has addressed Design, Engineering (offline) as well as Manufacturing (online) quality. This concept differentiates Taguchi technique from Statistical Process Control (SPC) which is purely an online quality control technique [10, 11].Taguchi ideas can be reduced into two fundamental concepts 1). Quality losses should be defined as deviation from target, not conformance to arbitrary specifications. [11] 2). To achieve high system quality levels economically requires quality to be designed into product. Quality is designed, not manufactured, into the product. [12, 13] Taguchi techniques represent a new philosophy. [14] Quality is measured by the deviation of a functional characteristic from its target value. Noises (uncontrollable factors) will cause such deviations which results in loss of Quality. Taguchi techniques seek to remove the effect of Noises. The most important part of the Taguchi technique is quality loss function [15].Taguchi has found that a quadratic function (parabola) approximates the behavior of loss in many cases [9].when the quality characteristic of interest is to be maximized or minimized, the loss function will become a half parabola [16]. Loss occurs not only when the product is outside its specification but also when product falls within its specification [17].

Work piece Material	Al 6063 with 10% Sic
Length of the work piece	75 mm
Diameter of the work piece	25.3 mm
Lathe Used	CNC Lathe
Measuring Instrument	Profilometer

Table 1: Experimental Conditions

Taguchi has recommended signal to noise ratio (S/N ratio) as performance statistics [18]. Signal refers to the change in quality characteristics of a product under investigation in response to a factor introduced in the experimental design. Noise refers to the effect of external factors (uncontrollable parameters) on the outcome of the quality characteristics [19].

3. Turning process parameters

The process parameters that are affecting the characteristics of turned parts are 1).Cutting Tool parameters-Tool geometry and Tool material. 2).Work piece related parameters – Hardness, Metallography. 3).Cutting parameters –Cutting Speed, Feed, Depth of Cut. 4).Environmental parameters-Dry cutting, Wet cutting. The following process parameters were selected for the present work: Cutting speed-(A), Feed-(B), Depth of Cut-(C), Work Material- Al 6063 alloy(table 2) with 10 % of Sic. The table 1 shows experimental conditions on turning. The ranges of the selected process parameters were ascertained by conducting preliminary experiments using one variable at a time approach

4. Experimental Results and Data Analysis

The plan of experiment is to find the important factors as shown in table 3 and combination of factors influencing the machining process to achieve the low surface roughness values by using smaller the better characteristic. Table 4 L9 Orthogonal Array design of experiment has been found suitable in the present work. Table 5 illustrates the experimental results. The purpose of analysis of variance is to determine the parameters and combination of parameters 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 appear to be significant. The experimental results were analyzed 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 are shown in table 6.

Si	Fe	Cu	Mn	Mg
0.20	0.35	0.10	0.10	0.45
Cr	Zn	Ti	Balance	
0.10	0.10	0.10	Al	

Table 2.chemical composition of Al 6063 alloy

Process Parameter	1	2	3
Speed	500	1000	1500
Feed	0.1	0.4	0.7
Depth of Cut	0.2	0.5	0.8

Table 3: Process parameters

Trial No.	**Speed (rpm)**	**Feed (mm/rev)**	**Doc (mm)**
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

Table 4: Standard L9 Orthogonal Array

PARAMETERS			**Roughness (Ra) (μm)**
Speed (rpm)	**Feed (mm/rev)**	**D O C (mm)**	
500	0.1	0.2	1.21
500	0.4	0.5	2.12
500	0.7	0.8	0.6
1000	0.1	0.5	3.23
1000	0.4	0.8	3.12
1000	0.7	0.2	2.01
1500	0.1	0.8	3.89
1500	0.4	0.2	3.96
1500	0.7	0.5	2.86

Table 5: Experimental Result of Surface Roughness

FACTOR	**DOF**	**SS**	**ADJ SS**	**MS**	**F TEST**	**P TEST**	**PR(%)**
A	2	7.9018	7.9018	3.9509	64.5451	0.0125	72.4237
B	2	2.5388	2.5388	1.2694	20.7382	0.1416	22.4961
C	2	0.1784	0.1784	0.0892	1.4574	0.0812	0.5213
ERROR	2	0.1224					**4.5589**
TOTAL	8	10.7414					100

Table 6: Standard L9 Array with Observations

Level	a	b	c
1	-1.248	-7.88	-6.558
2	-8.71	-9.455	-8.613
3	-10.96	-3.585	-5.748
Delta	9.712	5.87	2.864
Rank	1	2	3

Table 7: Response Table for Signal to Noise Ratios Smaller is better

Level	a	b	c
1	1.31	2.777	2.393
2	2.787	3.067	2.737
3	3.57	1.823	2.537
Delta	2.26	1.243	0.343
Rank	1	2	3

Table 8: Response Table for Means

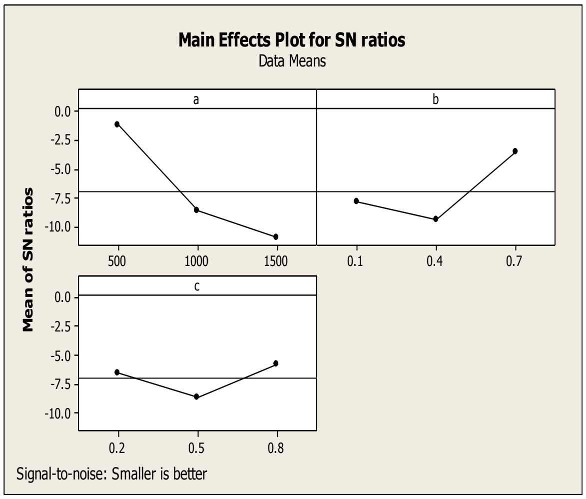

Figure 1: S/N ratio values for Surface Roughness

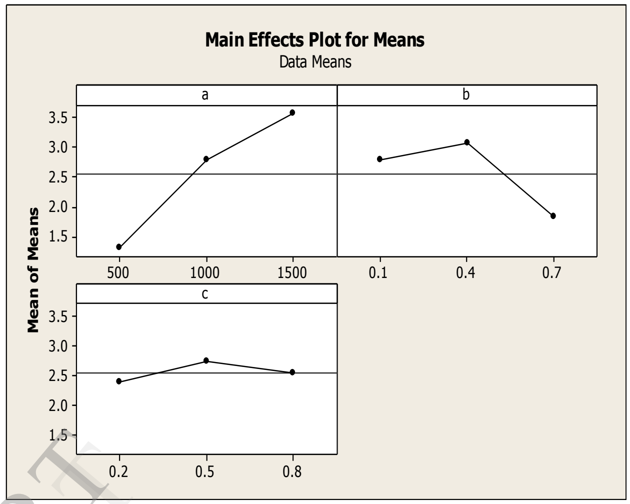

Figure 2: Means values for Surface Roughness

From these experimental results with the help of signal to noise ratio, the optimum conditions resulting in surface roughness is shown in figures 1 and 2

4.1 Regression Model for Surface Roughness:

Using Minitab Software the Regression Model has been developed for the above Experiment. The regression equation is

Ra = 0.812 + 0.00226 Speed (rpm) - 1.59 Feed (mm/rev) + 0.239 Depth of Cut (mm)

S = 0.580679 R-Sq = 84.3% R-Sq (adj) = 74.9%

5. Conclusion:

i) From the results obtained a Regression Model has been developed for Surface Roughness. From this equation we can predict the value of Surface Roughness if the values ofCutting Speed, Feed and Depth of Cut are known.

ii) From ANOVA Table 6 and Response Table 7 for Signal to Noise ratios, based on the ranking it can be concluded that Speed has a greater influence on the Surface Roughness followed by Feed. Depth of Cut had least influence on Surface Roughness.

iii) The validation experiment confirmed that the error occurred was less than 2.0 % between equation and actual value.

iv) The optimal settings of process parameters for optimal Surface Roughness are: Speed (500 rpm), Feed (0.7 mm/rev), and DOC (0.8 mm).

This research gives us how to use Taguchi's parameter design to obtain optimum condition with lowest cost, minimum number of experiments and Industrial Engineers can use this method

References

[1] E.J.A Armarego and R.H Brown, The machining of metals prentice Hall, 1969

[2] R.C Brewer and R. Rueda , “A Simplified Approch to the optimum selection of machining parameters ", Engines Digest vol.24,NO.9,PP 133-150

[3] R.M Sundaram, “An application of Goal programming technique in metal cutting”,Int.j.prod.Res.,vol.16,NO5,1978,PP375-382

[4] P.G Petropoulos, “optimum selection of machining rate variable by Geometric programming ”,Int .J .prod .Res,vol.11,NO,4,1973 PP 305-314

[5] A.Mital, M.Mehta, “surface roughness Prediction models for fine turning”, International journal of production research 26 (1988) 1861-1876

[6] C.A.Van Luhervelt,T.H.C Childs,I.S Jawahir,F.Klocke.P.K.Venuvinod.present situation & future trends modeling of machining operations.progress report of the CIRP Working group “Modelling of machining operations” Annalysis of the CIRP, 47/2(1998)587- 626

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[7] R.Azouzi,M.Guillot, “on-line optimization of the turning using an inverse process neuro controller translation” ASME , journal of manufacturing science and engineering 120 (feb)(1998)101-107

[8] Erdal O, Sonmez FO. Optimum design of composite laminates for maximum buckling load capacity using simulated annealing. Compos Struct 2005;71:45–52.

[9] Barker.T.B , Engineering quality by design ,(Marcel Dekker ,Inc, newyork),1990

[10] Pekbey Y, Ozdamar A, Sayman O. Buckling optimization of composite columns with variable thickness. J Reinf Plast Compos 2007;26:1337–56.

[11] Benton W C, Int J Prod Res , 29(1991) 1761-1770

[12] Liu PF, Zheng JY. Recent developments on damage modeling and finite element analysis for composite laminates: a review. Mater Des 2010;31:3825–34.

[13] Taguchi G,Quality engineering in production systems ,(M C Graw-Hill ,Newyork), 1989

[14] Lin Paul K H, sullivan L P & Taguchi G ,Qual progr,(1990) 55-59.

[15] D.R. Cox, N. Reid, The Theory of the Design of Experiments, Chapman & Hall/CRC Press, London/Boca Raton, FL, 2000.

[16] Byrne D.M & Taguchi S, Qaul progr,(1987) 19-26.

[17] Ross philip J, Taguchi techniques for quality engineering (M C Graw-Hill book company, Newyork), 1996.

[18] P.J. Ross, Taguchi Techniques for Quality Engineering, McGraw-Hill, New York, 1989.

[19] Roy Ranjit .K ,A primer on Taguchi method ,(van Nostrand Reinhold ,Newyork),1990