PROCESS PARAMETERS OPTIMIZATION OF CNC TURNING MACHINE FOR ALUMINIUM ALLOY USING TAGUCHI METHOD

Himanshu Sonar[1], Vishudha Saxena[2], Vivek Kshirsagar[3], Shraddha P Deshpande[4]

[1] *BE, Department of Mechanical Engineering, GESRHSCOE Nasik, Maharashtra, India*
[2] *BE, Department of Mechanical Engineering, GESRHSCOE Nasik, Maharashtra, India*
[3] *BE, Department of Mechanical Engineering, GESRHSCOE Nasik, Maharashtra, India*
[4] *Assistant Professor, Department of Mechanical Engineering, GESRHSCOE Nasik, Maharashtra, India*

Abstract

In modern machining industries the challenge arises for manufacturing good quality product which is also cost effective. Turning is a major machining operation which is removing of material from the surface of rotating cylindrical work piece. Material removing rate and surface roughness are two important aspects concerning the quality of turning operation. In this paper Taguchi method is studied and implemented for system design and process parameters design such as selecting depth of cut, feed rate and speed of CNC turning machine for aluminium alloy. There are four parameters with three different suitable levels and based on this the orthogonal array was selected (L9). Nine runs were carried out using three different cutting tool insert with reference to the orthogonal array selected. The target material used in this paper was Al6061 T6. Result and analysis was carried out using regression modeling and polynomial equations were generated and optimum machining parameters were determined. Using this polynomial equation the surface roughness and material removing rate can be predicted.

***Keywords:** Turning, Surface Roughness, MRR, Taguchi Method, Orthogonal Array, Al 6061 T6, Regression Modeling*

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1. INTRODUCTION

Turning is a vital machining operation, which removes material from the surface of a rotating cylindrical work piece using a single point cutting tool. Turning operation is done to reduce the diameter of the work piece according to required diameter, and also to achieve a good surface finish on the work pieces. The tool used for cutting is fed linearly, parallel to the axis of rotation of work piece. [1]

In modern industry, is to manufacture low-cost, high quality products with maximum productivity in a short time. Turning is the most common method for cutting and especially for the finishing of machined parts. Furthermore, in order to produce with desired quality and maximum productivity of machine, cutting parameters should be selected properly. [2]

1.1 Introduction to Taguchi Method

Taguchi method was proposed by Dr. Genichi Taguchi in 1950'sTaguchi method is statistical tool, adopted experimentally to investigate influence of surface roughness by cutting parameter such as feed, spindle speed and depth of cut. The Taguchi process helps to select or to determine the optimum cutting parameters for turning process. [3]

2. EXPERIMENTAL SETUP

2.1 Material Used

Aluminium Al6061 T6 was used as the target material in this paper. The chemical composition is mentioned in Table 1. The work piece were of dimensions, 40 mm diameter and total length of 150 mm out of which 90mm was machining length and rest was used for holding the work piece. (ASM Aerospace specifications Metals Inc. ASM.metweb.com)

Table-1 Chemical Composition of Al 6061 T6

Component	Wt. %	Component	Wt. %
Al	95.8-98.6	Mg	0.8-1.2
Cr	0.04-0.35	Mn	Max 0.15
Cu	0.15-0.4	Si	0.4-0.8
Fe	Max 0.7	Zn	Max 0.2
Ti	Max 0.15	Other total	Max 0.15

2.2 Equipment Used

The different equipment used in this investigation are listed below in Table 2

Table-2 Equipment List

Item	Specification
CNC Lathe	Hytech CNC Lathe trainer machine Spindle speed range: 50rpm minimum and 3000rpm maximum Feed rate: 400mm/min maximum
Surface roughness measurement device	Mitutoyo surface roughness tester Measuring unit: R_a in µmm Stylus travel: 4.8mm
Cutting tool insert	T1: Alumina K10 Coating layer- uncoated T2: Taegutech TT8020 Coating type- PVD Coating layer- TiCN T3: Taegutech TT5100 Coating type- CVD Coating layer-TiCN-Al_2O_3- TiN

2.3 Machining Parameters

Machining parameters such as feed rate, spindle speed and depth of cut and their suitable levels are mentioned in Table 3

Table-3 Machining Parameters

Parameters	Codes	Level 1	Level 2	Level 3
Spindle speed (rpm)	X1	800	1200	1600
Depth of cut (mm)	X2	0.2	0.3	0.4
Feed (mm/min)	X3	80	120	160
Cutting tool insert	X4	T1	T2	T3

2.4 Parameter Design

Next step in Taguchi method is parameter design which consists of selection of orthogonal array, run experiments, analyze data, identify optimum condition and confirming the test results. The orthogonal array used in this investigation is mentioned below in Table 4. [5]

Table-4 Orthogonal Array

Run	X1	X2	X3	X4
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

The runs are experimentally carried out according to the orthogonal array as mentioned in Table 4 and the values of material removal rate and surface roughness are measured and recorded in tabular form as in Table 5. Material removal rate (MRR) is the volume of material removed because of turning divided by the time required to remove that much volume.

Table-5 Experimental Setup Sheet with MRR and Surface Roughness

Run	Spindle Speed (rpm)	Depth Of Cut (mm)	Feed $\frac{mm}{min}$	Cutting Tool Insert	Surface Rough-ness (R_a)	MRR $\frac{mm3}{sec}$
1	800	0.2	80	T1	2.96	17.58
2	800	0.3	120	T2	4.65	39.31
3	800	0.4	160	T3	7.19	70.35
4	1200	0.2	120	T3	6.78	26.43
5	1200	0.3	160	T1	2.72	52.67
6	1200	0.4	80	T2	2.15	35.28
7	1600	0.2	160	T2	2.91	35.48
8	1600	0.3	80	T3	2.05	26.85
9	1600	0.4	120	T1	3.13	52.47

3. RESULT AND ANALYSIS

In this paper regression modeling method is applied. Microsoft Excel was used for regression modeling for this investigation. A polynomial equation is obtained with the help of regression modeling for each surface roughness and material removing rate, and it is easy to manipulate polynomial equations. Table 6 shows the input data sheet for regression modeling. [5]

Table-6 Input Data Sheet for Regression Modeling

Run	X1	X2	X3	X4	X1X2	X1X3	X1X4	X2X3	X2X4	X3X4	Surface Roughness	MRR
1	800	0.2	80	1	160	64000	800	16	0.2	80	2.96	17.58
2	800	0.3	120	2	240	96000	1600	36	0.6	240	4.65	39.31
3	800	0.4	160	3	320	128000	2400	64	1.2	480	7.19	70.35
4	1200	0.2	120	3	240	144000	3600	24	0.6	360	6.78	26.42
5	1200	0.3	160	1	360	192000	1200	48	0.3	160	2.72	52.67
6	1200	0.4	80	2	480	96000	2400	32	0.8	160	2.15	35.28
7	1600	0.2	160	2	320	256000	3200	32	0.4	320	2.91	35.48
8	1600	0.3	80	3	480	128000	4800	24	0.9	240	2.05	26.86
9	1600	0.4	120	1	640	192000	1600	48	0.4	120	3.13	52.47

Using this data in Microsoft Excel the regression modeling is done and modeling for surface roughness and material removing rate are shown in Table 7 and Table 8 respectively.

Table-7 Output Summary for Surface Roughness

Regression Statistics	
Multiple R	0.998495639
R Square	0.99699354
Adjusted R Square	-2.024051677
Standard Error	0.300223462
Observations	9

ANOVA

	df	SS	MS	F
Regression	10	28.890021	2.989002	47.377
Residual	1	0.0901341	0.090134	
Total	11	29.980155		

	Coefficients	*t Stat*
Intercept	-37.06126984	-6.87614
X1	0.040421825	6.312714
X2	0	65535
X3	0.406865079	7.204347
X4	0	65535
X1X2	0.018911706	2.781225
X1X3	-0.000303395	-7.60597
X1X4	-0.006126687	-8.31548
X2X3	-0.495992063	-6.18867
X2X4	0	65535
X3X4	0.054206349	10.49506

This is the mathematical polynomial equation obtained from above modeling which can be used to predict the surface roughness for any given machining parameters.

$$Ra = -37.061269 + (0.040421X1) + (0.406865X3) + (0.018911X1X2) - (0.000303X1X3) - (0.006126X1X4) - (0.495992X2X3) + (0.054206X3X4)$$

Table-8 Output Summary for MRR

Regression Statistics	
Multiple R	0.999996816
R Square	0.999993632
Adjusted R Square	-2.000050948
Standard Error	0.116704076
Observations	9

ANOVA

	df	SS	MS	F
Regression	10	2138.631936	213.8632	22431.89
Residual	1	0.013619841	0.01362	
Total	11	2138.645556		

	Coefficients	*t Stat*
Intercept	4.896984127	2.337284
X1	-0.003740873	-1.50291
X2	0	65535
X3	-0.063007937	-2.87011
X4	0	65535
X1X2	-0.005941468	-2.2478
X1X3	3.76066E-05	2.425318
X1X4	0.000766567	2.67652
X2X3	1.189206349	38.17143
X2X4	0	65535
X3X4	-0.004884921	-2.43305

This is the mathematical polynomial equation obtained from above modeling which can be used to predict the material removing rate for any given machining parameters.

$$MRR = 4.89698 - (0.00374X1) - (0.06301X3) - (0.00594X1X2) + (3.766E - 05X1X3) + (0.000767X1X4) + (1.189206X2X3) - 0.00488X3X4$$

Substituting the value of machining parameter i.e. the value of X1, X2, X3, X4, from the orthogonal array in above two equations of MRR and surface roughness we get the result as shown in Table 9.

Table-9 Result Table

Run	X1	X2	X3	X4	Surface Roughness	MRR
1	800	0.2	80	1	2.96	17.57
2	800	0.3	120	2	4.90	39.40
3	800	0.4	160	3	7.21	70.35
4	1200	0.2	120	3	6.73	26.39
5	1200	0.3	160	1	2.69	52.64
6	1200	0.4	80	2	2.08	35.25
7	1600	0.2	160	2	3.07	35.52
8	1600	0.3	80	3	2.15	26.89
9	1600	0.4	120	1	3.29	52.50

From the Table 9 lowest value of surface roughness is 2.08 R_a for the machining parameters depth of cut = 0.4mm, spindle speed = 1200 rpm, feed rate = 80 mm/min, and cutting tool insert – TT8020. Maximum material removing rate is 70.35 mm^3/sec for the machining parameters depth of cut = 0.4mm, spindle speed = 800 rpm, feed rate = 160 mm/min, and cutting tool insert – TT5100.

4. CONCLUSION

This paper presented, regression method for optimizing the process parameters of CNC turning machine for material removing rate and surface finish under different levels and cutting tool insert with help of Taguchi approach for parameter design process. The orthogonal array used was L_9, with four machining parameters, three levels and aluminium alloy Al6061 T6 as test work piece. The equations of material removing rate and surface roughness obtained from regression modeling can use for predicting material removing rate and surface roughness respectively for decided machining parameters and hence the parameters are acceptable or not can be justified.

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BIOGRAPHIES

Himanshu Sonar is currently a student of GESRHSCOE, Nasik, Maharashtra, India from SPPU Pune. Has an interest in manufacturing and design

Vishudha Saxena is currently a student of GESRHSCOE, Nasik, Maharashtra, India from SPPU Pune. Has an interest in manufacturing and production

Vivek Kshirsagar is currently a student of GESRHSCOE, Nasik, Maharashtra, India from SPPU Pune. Has an interest in material Science and metallurgy

Mrs Shraddha P Deshpande has completed BE (Mech), ME (Production), and currently pursuing PhD from SVNIT, Surat and is an Asst Prof in GESRHSCOE, Nasik, Maharashtra, India from SPPU Pune. Has an interest in optimization and manufacturing