Single Objective Optimization of Process Parameters considering Insert Nose Radius in CNC Turning of Aluminium 7075 Alloy for MRR and Surface Roughness

Navneet Saini[1]
PG student Industrial and Production Engineering,
Modern Institute of Engineering and Technology,
Mohri, Ambala, India

Jitender Panchal[2]
Assistant Professor,
Department of Mechanical Engineering,
Modern Institute of Engineering and Technology,
Mohri, Ambala, India

Mohd Muqeem[3]
Assistant Professor,
Department of Mechanical Engineering,
IFTM University
Moradabad, India

***Abstract* - Machining process involves many process parameters. In order to obtain accurate dimensions, good surface quality, and maximized metal removal it is necessary to optimize the process parameters involved in machining operation. The aim of the present paper is to obtain the optimal parameters of turning process (cutting speed, feed rate, depth of cut and nose radius) which results in minimum surface roughness and maximum material removal rate for machining aluminum 7075 alloy in CNC turning by using coated carbide inserts of different nose radius. Surface roughness was measured using the SJ-201 surface roughness tester and material removal rate was calculated using MRR equation.**

In this study, Taguchi method is used to find the optimal cutting parameters for surface roughness in turning. L-16 orthogonal array, signal-to-noise ratio, and ANOVA are employed to study the performance characteristics in the turning operations of aluminum 7075 alloy. A precise knowledge of these optimum parameters would result in reduction of machining costs and improved product quality.

Keywords— MRR, Surface roughness, ANOVA, Taguchi

I. INTRODUCTION

Manufacturing companies seek for high productivity and low surface roughness to produce a good quality product at minimal cost and within minimum possible time. These outputs are the most critical considerations in the turning process. Thus, the selection of machining parameters, such as cutting speed, feed rate, depth of cut and nose radius is very important because they directly influence the quality and productivity of the product. In addition, selecting machining parameters that can provide good performance for MRR and surface roughness is needs optimization techniques that can provide best results [1,2]].

By reviewing the work done by previous researchers [1- 12], it is found that a considerable amount of work has been done before by previous investigators for parametric optimization of surface properties and MRR in turning operation. Issues related to tool life, tool wear, cutting forces have been addressed to. But a very little work has been found using inserts with different nose radius as a parameter for optimizing the surface properties. This study demonstrates detailed methodology of the proposed optimization technique which is based on Taguchi method that helps in optimizing the input parameters such as cutting speed, feed, depth of cut and nose radius of inserts through S/N ratio. MRR of a turned product along with surface finish of work piece have been optimized individually.

A. Turning operation parameters

In CNC turning process parameters involved in the study are speed (V), Feed rate (F), Depth of cut (D) and Insert Nose Radius (N) which needs to be optimized for maximizing material removal rate and minimizing surface roughness.

B. Material Removal Rate

The material removal rate (MRR) in turning operations is the volume of metal that is removed per unit time in mm3/min. For each revolution of the work piece, a ring shaped layer of material is removed.

Material Removal Rate (MRR) equation for Turning:

$$MRR = \pi \text{ D DOC Fm} \qquad mm^3/min$$

Where D= original diameter of work piece in mm

DOC= depth of cut in mm and Fm = feed rate in mm/min

C. Surface Roughness

Surface roughness most commonly refers to the average variation in the height of the surface relative to a reference plane [8]. It was measured directly by using surface roughness tester, SJ-201.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 06, June - 2017

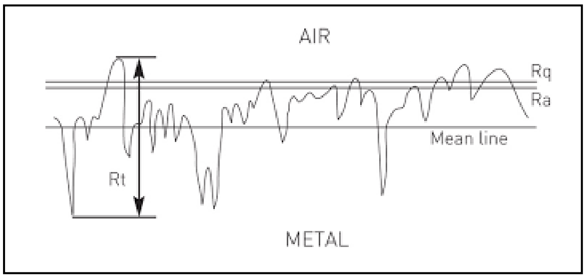

Figure1. Surface roughness parameters

II. PROBLEM DEFINITION

Turning is an important metal cutting operation which is extensively used in the manufacturing industry. Metal removal rate and surface finish are the important output responses in the turning operation with respect to quantity and quality. Based on the literature review it can be observed that turning parameters like speed, feed rate, depth of cut and nose radius influence the response variables like material removal rate and surface roughness, so they need to be optimized for getting the best results.

III.DESIGN OF EXPERIMENTS

Input parameters or control factors and their levels involved in a study helps to decide the design of experiment (DOE) to be chosen according to which the experimentation is further conducted. In the present experiment L_{16} array is designed by using Taguchi technique and then further experimentation is advanced accordingly. Robustness of the selected design is also ensured to minimize the noise factor. A design is called robust when it has minimum effect of the noise or uncontrollable factors on the response variables. Details of experiment and analysis technique used in the present study is described in the following sections

A. Selection of Orthogonal Array- Taguchi Method

An orthogonal array (OA) was designed by Taguchi technique which was further used to investigate the effect of input parameters (speed, feed, DOC and nose radius) on the response variables with lesser number of experiments. OA was selected which was based on the number of input parameters and their levels involved in the experimentation. The number of input parameters and their levels, helps in designing the orthogonal array which is obtained from the relation (L-1) P + 1, where L is the number of levels and P is the number of input parameters. In the present study, since L = 4 and P = 4, therefore, minimum number of experiments required to be performed is (4-1) x 4 + 1 = 13. Therefore, in the present

study L_{16} orthogonal array was selected. Statistical software such as Minitab-17 was used to select standard OA and to perform the data analysis [14-16].

B. Selection of control levels

Four levels denoted by L of each control parameters (speed, feed rate, DOC and nose radius) were taken as shown in table below in view of previous research work [1-6]

Table 1: Process parameters and their levels

Parameters	Unit	L-1	L-2	L-3	L-4
Nose radius	mm	0.2	0.4	0.8	1.2
Speed	rpm	600	800	1000	1200
Feed rate	mm/min	40	60	80	100
DOC	mm	0.2	0.4	0.6	0.8

IV.EXPERIMENTAL SET UP

The setup used for experimentation in the present study consists of computer numerical control M-TAB company machine. In CNC system a dedicated computer is used to perform all the basic functions as per the executive program stored in the computer memory. The system directs commands to servo drives to drive the servo motor & other output devices like relays, solenoids etc. to initiate the operations such as motor starting & stopping, coolant on & off, tool changing, pallet changing etc. and other miscellaneous functions..Some sensors like proximity switch, limit switch, pressure switch, flow switch and float switch etc. are used as feedback devices to monitor the miscellaneous operations. Thus all operations or CNC machine are monitored continuously with appropriate feedback devices.

Fig. 2: M TAB CNC lathe machine

A surface roughness tester SJ-201 was used to directly measure the Arithmetic mean value of Surface Roughness with 0.8mm testing length

Fig. 3: SJ-201 Surface Roughness tester

A.Material Selection

The experiment was performed with turning of AL 7075-T6 alloy (a high strength aluminium alloy used for aerospace applications).work piece of 40 mm length and 25.4 mm diameter per piece was used. A total of 16 samples were cut to the aforesaid dimension to perform the experiment.,2 additional work piece were used to conduct the confirmation experiment

B. Cutting tool Inserts

The cutting tool selected for machining of AL 7075-T6 is coated cemented carbide insert an excellent material for the machining of aluminum and its alloys. Inserts having standard nose radius of 0.2, 0.4, 0.8 and 1.2 were taken to perform the machining and these nose radius were taken as one of the input parameter that influences the output parameter such as MRR and surface roughness.

C. Machine Tool

The machining is done on a 2 axis CNC lathe of M TAB Company and the work piece was mounted on a pneumatic chuck and then machining program was entered in the CNC according to the selected input parameters. A simulation check is done for each run to avoid errors in programming and machining. The turning process is carried out according to the experimental chart designed using orthogonal array.

Table 2: Specification of CNC lathe (M TAB) machine

Make	M TAB Chennai
Chuck size	100 mm
Max. turning diameter	32 mm
Max. turning length	120 mm
Spindle speed range	150-3000 rpm
Feed rate	0-100 mm/min

V.RESULTS AND DISCUSSIONS

A. Single objective optimization for Material Removal rate (MRR) and Surface Roughness

In this technique both the parameters MRR and surface roughness were optimized individually by using Taguchi methodology and main effect plot for SN ratio of both parameters were drawn and a regression equation was established between response variables and controllable parameters ANOVA table for both the objectives was analyzed[8,9].

B. Analysis of S/N ratio for MRR

For MRR larger-the-better criterion was used as the objective was to maximize it and S/N ratio was calculated using Eq. (1).

The S/N ratio for larger-the better characteristic is expressed as:

$$= -10log\left[\frac{1}{r}\sum_{i=1}^{r}\frac{1}{y_i^2}\right] \qquad (1)$$

where y_i is the mean of the measured values of the response variable of i^{th} experiment and r is the number of experiments at a particular level of control factor in an orthogonal array. The negative sign ensures that the largest value gives an optimum value of the response variable

Table 3: S/N Ratio for MRR (larger the better)

S.NO.	Speed	Feed	DOC	NR	MRR	S/N Ratio for MRR
1	600	40	0.2	0.2	638.05	56.10
2	600	60	0.4	0.4	1914.14	65.64
3	600	80	0.6	0.8	3828.29	71.66
4	600	100	0.8	1.2	6380.48	76.10
5	800	40	0.4	0.8	1276.10	62.12
6	800	60	0.2	1.2	957.07	59.62
7	800	80	0.8	0.2	5104.38	74.16
8	800	100	0.6	0.4	4785.36	73.60
9	1000	40	0.6	1.2	1914.14	65.64
10	1000	60	0.8	0.8	3828.29	71.66
11	1000	80	0.2	0.4	1276.10	62.12
12	1000	100	0.4	0.2	3190.24	70.08
13	1200	40	0.8	0.4	2552.19	68.14
14	1200	60	0.6	0.2	2871.22	69.16
15	1200	80	0.4	1.2	2552.19	68.14
16	1200	100	0.2	0.8	1595.12	64.06

C. S/N Graph for Material Removal rate (MRR)

On analyzing the Taguchi design of experiment for the collected data using Minitab software, S/N graphs for MRR is shown below. Irrespective of the criterion of maximizing or minimizing the response variable, highest value of the mean S/N ratio is always considered in their optimization.

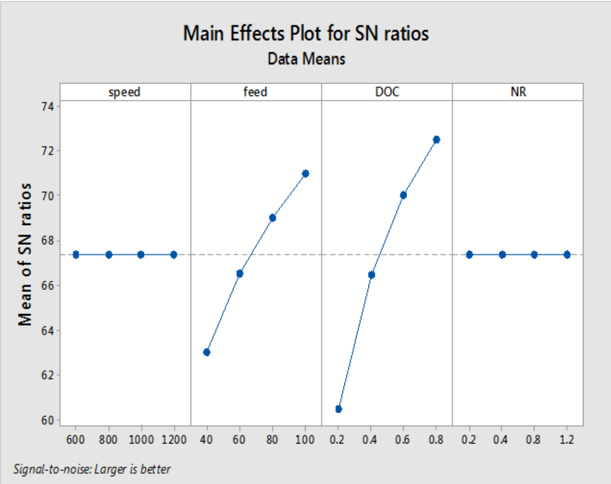

Fig. 4: S/N graph for MRR

Optimum settings from graph is V1-F4-D4-N1, where v is speed in rpm, F is feed rate in mm/min, D is depth of cut in mm and N is nose radius in mm

Table 4: Factor level of prediction from S/N graph

Speed	Feed	DOC	NR
600	100	0.8	0.2

D.ANOVA (Analysis of variance for MRR)

An ANOVA table is commonly used to summarize the tests performed. It is evident that speed, feed, depth of cut and nose radius are significant at 95% confidence level and thus affects mean value [10, 11].

It can be observed that percentage contribution of various control parameters is shown in table below which signifies that DOC has highest contribution for MRR followed by feed rate, speed and nose radius

Table 5: Analysis of Variance (ANOVA) for MRR

Source	DF	Adj SS	Adj MS	P-Value	% Contribution
speed	3	1730195	576732	0.133	4.30
feed	3	12722039	4240680	0.009	31.65
DOC	3	24935174	8311725	0.003	62.03
NR	3	407101	135700	0.500	1.01
Error	3	407114	135705		
Total	15	40201624			

Response table shows the rank of control parameters means in which order they influence the MRR which is DOC>Feed >NR> speed

Table 6: Response Table for Signal to Noise Ratios (Larger is better)

Level	Speed	Feed	DOC	NR
1	67.37	63.00	60.47	67.37
2	67.37	66.52	66.49	67.37
3	67.37	69.02	70.01	67.37
4	67.37	70.96	72.51	67.37
Delta	0.00	7.96	12.04	67.37
Rank	4	2	1	3

E. Predicted value for MRR

Prediction of MRR at optimum settings can be given by using Minitab software under Taguchi analysis

Table 7: Predicted value of MRR and corresponding S/N Ratio

Predicted S/N ratio	Predicted MRR in mm^3/min
76.0971	6220.97

F. Experimental value

Experimental value of MRR was measured at optimum control parameters by performing the experiment and then the corresponding S/N ratio was calculated by using equation (1)

Table 8: Experimental value of MRR and corresponding S/N Ratio

Experimental S/N ratio	Experimental MRR in mm^3/min
75.64	6054.20

G. Comparison of Results

Confirmation test revealed good agreement between predicted and experimental values of the MRR at optimum combination of the input parameters, which means that V1-F4-D4-N1 can be chosen as the optimum set of input parameters for maximizing MRR.

H. Analysis of S/N ratio for Surface Roughness

For surface roughness (Ra) smaller-the-better criterion was used as the objective was to minimize it and S/N ratio was calculated using Eq. (2).

The S/N ratio for smaller-the-better characteristic is given as:

$$= -10log\left[\frac{1}{r}\sum_{i=1}^{r} y_i^2\right] \quad (2)$$

where y_i is the mean of the measured values of the response variable of i^{th} experiment and r is the number of experiments at a particular level of control factor in an orthogonal array. The negative sign ensures that the largest value gives an optimum value of the response variable.

Table 9: S/N Ratio for Surface Roughness (Smaller the better)

S.NO.	Speed	Feed	DOC	NR	Ra	S/N ratio for Ra
1	600	40	0.2	0.2	1.14	-1.14
2	600	60	0.4	0.4	1.26	-2.01
3	600	80	0.6	0.8	1.33	-2.48
4	600	100	0.8	1.2	1.01	-0.09
5	800	40	0.4	0.8	1.51	-3.58
6	800	60	0.2	1.2	0.49	6.20
7	800	80	0.8	0.2	1.46	-3.29
8	800	100	0.6	0.4	1.40	-2.92
9	1000	40	0.6	1.2	0.50	6.02
10	1000	60	0.8	0.8	0.84	1.51
11	1000	80	0.2	0.4	1.07	-0.59
12	1000	100	0.4	0.2	1.89	-5.53
13	1200	40	0.8	0.4	1.03	-0.26
14	1200	60	0.6	0.2	1.00	0.00
15	1200	80	0.4	1.2	0.65	3.74
16	1200	100	0.2	0.8	0.94	0.54

I. S/N Graph for Surface Roughness (Ra)

On analyzing the Taguchi design of experiment for the collected data using Minitab software, S/N graphs for Ra is shown below. Irrespective of the criterion of maximizing or minimizing the response variable, highest value of the mean S/N ratio is always considered in their optimization.

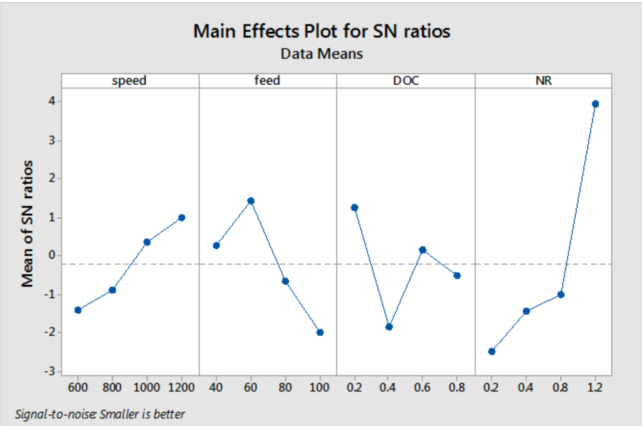

Fig. 5: S/N graph for Surface Roughness

Optimum settings from graph is V4-F2-D1-N4, where v is speed in rpm, F is feed rate in mm/min, D is depth of cut in mm and N is nose radius in mm

Table 10: Factor level for prediction from S/N graph

Speed	Feed	DOC	NR
1200	60	0.2	1.2

J.ANOVA (Analysis of variance for Ra)

An ANOVA table is commonly used to summarize the tests performed. It is evident that speed, feed, depth of cut and nose radius are significant at 95% confidence level and thus affects mean value

It can be observed that percentage contribution of various control parameters is shown in table below which signifies that NR has highest contribution for surface roughness (Ra) followed by DOC, feed rate and speed.

Table 11: Analysis of Variance (ANOVA) for Surface Roughness

Source	DF	Adj SS	Adj MS	P-Value	% contribution
Speed	3	0.2360	0.07867	0.215	11.01
Feed	3	0.3551	0.11838	0.138	16.57
DOC	3	0.3591	0.11972	0.136	16.76
NR	3	1.1067	0.36892	0.032	51.54
Error	3	0.0861	0.02872		
Total	15	2.1432			

Response table shows the rank of control parameters means in which order they influence the surface roughness (Ra) which is NR>Feed >DOC> speed

Table 12: Response Table for Signal to Noise Ratios (Smaller is better)

Level	Speed	Feed	DOC	NR
1	-1.4272	0.2616	1.2519	-2.4886
2	-0.8983	1.4258	-1.8436	-1.4436
3	0.3545	-0.6525	0.1553	-1.0012
4	1.0056	-2.0002	-0.5290	3.9680
Delta	2.4328	3.4260	3.0956	6.4566
Rank	4	2	3	1

K. Predicted value for Surface Roughness (Ra)

Prediction of MRR at optimum settings can be given by using Minitab software under Taguchi analysis

Table 13: Predicted value of Ra and corresponding S/N Ratio

Predicted S/N ratio	Predicted Ra in µm
20.91515	0.09

L. Experimental value

Experimental value of MRR was measured at optimum control parameters by performing the experiment and then the corresponding S/N ratio was calculated by using equation (2)

Table 14: Experimental value of MRR and corresponding S/N Ratio

Experimental S/N ratio	Experimental Ra in µm
18.41638	0.12

M. COMPARISON OF RESULTS

Confirmation test revealed good agreement between predicted and experimental values of the Ra at optimum combination of the input parameters, which means that V4-F2-D1-N4 can be chosen as the optimum set of input parameters for minimizing surface roughness (Ra).

VI. CONCLUSION

Single-objective Optimization for High Speed Turning of Al 7075 using Taguchi Analysis is discussed in this paper. Based on the analysis following conclusions can be made.

- Taguchi Analysis is very effective technique for optimization of machining parameters involved
- It can be concluded from the response table that control parameters affecting the response variables for MRR follow the descending order which is DOC >Feed >NR >speed and for surface roughness response variables follow the descending order NR>Feed >DOC> speed
- The recommended set of cutting parameters for high speed turning of Al 7075 for maximum MRR is 600 rpm Speed, 100 mm/min feed rate, 0.8 mm DOC and 0.2 mm NR, and for minimum value of surface roughness it is 1200m/min, 60mm/min, 0.2mm and 1.2mm with coated carbide insert and under dry machining conditions.
- Confirmation test revealed good agreement between predicted and experimental values of the MRR and surface roughness at optimum combination of the input parameters.

REFERENCES

[1] Feng, C.X. and Wang X, Development of empirical models for surface roughness prediction in finis turning. International Journal of Advanced Manufacturing Technology; 2002, Vol. 20, pp.348-356.

[2] Lambert, B.K.; Determination of metal removal rate with surface finish restriction. Carbide and tool Journal, May – June : 16-19, 1983.

[3] Ho SY , Lee KC, Chen SS, Ho SJ; Accurate Modeling prediction of surface roughness by computer vision in turning operation using an adaptive neuro- fuzzy inference system. Int J Mach Tools Manuf, 2002; 42:1441-1446.

[4] Malakooti B. and Raman V.; An Interactive Multi –Objective artificial neural network approach for machine setup optimization, Journal of Intelligent Manufacturing, 2000, Vol. 111, pp 41-50.

[5] Rasch and Roistadas; Series of finish turning tests under variation of parameters : Material quality ., Tool quality , Tool nose radius , feed speed and cutting time. Journal of material processing technology, 1971, Vol-132, 203-214.

[6] Tian-Syung Lan and Ming-Yung Wang; Competitive parameter optimization of multi-quality CNC turning; The International Journal of Advanced Manufacturing Technology; April 2009, Volume 41, Issue 7-8, pp 820-826.

[7] Zhang Xueping, Gao Erwei and C. Richard Liu; Optimization of process parameter of residual stresses for hard turned surfaces; Journal of Materials Processing Technology; Volume 209, Issue 9, 1 May 2009, Pages 4286–4291

[8] S.J. Raykara, D.M. D'Addonab, A.M. Manea,“Multi-objective optimization of high speed turning of Al 7075 using grey relational analysis”,9th CIRP Conference on Intelligent Computation in Manufacturing Engineering, Procedia CIRP 33 (2015) 293 – 298

[9] P. Jayaramana, L. Mahesh kumar, “Multi-response Optimization of Machining Parameters of TurningAA6063 T6 Aluminium Alloy using Grey Relational Analysis in Taguchi Method”, 12th GLOBAL CONGRESS ON MANUFACTURING AND MANAGEMENT, GCMM 2014, Procedia Engineering 97 (2014) 197 – 204

[10] Rishu Gupta, Ashutosh Diwedi, “Optimization of Surface Finish and Material Removal Rate with Different Insert Nose Radius for Turning Operation on CNC Turning Center”, International Journal of Innovative Research in Science,Engineering and Technology, Vol. 3, Issue 6, June 2014

[11] Devendra Singh, Vimanyu Chadha and Ranganath M Singari, “effect of nose radius on surface roughness during cnc turning using response surface methodology”, International Journal of Recent advances in Mechanical Engineering (IJMECH) Vol.5, No.2, May 2016

[12] Srinivas Athreya1,Dr Y.D.Venkatesh, “Application Of Taguchi Method For Optimization Of Process Parameters In Improving The Surface Roughness Of Lathe Facing Operation”, International Refereed Journal of Engineering and Science (IRJES) ISSN (Online) 2319-183X, (Print) 2319-1821 Volume 1, Issue 3 (November 2012), PP.13-19

[13] D'Addona,D.M., Teti, R., 2013, Genetic Algorithm-based Optimization of Cutting Parameters in Turning Processes, Procedia CIRP, Vol. 7, 2013, ISSN 22128271: 323-328

[14] T. K Durga Bhavani , G. S .V Seshu Kumar, Prof. K Satyanarayana, I. Ajit Kumar,Optimization of Material Removal Rate and Surface Roughness in Turning of Aluminum, Copper and Gunmetal Materials using RSM

[15] Lambert, B.K.; Determination of metal removal rate with surface finish restriction. Carbide and tool Journal, May – June : 16-19, 1983.

[16] Ho SY , Lee KC, Chen SS, Ho SJ; Accurate Modeling prediction of surface roughness by computer vision in turning operation using an adaptive neuro- fuzzy inference system. Int J Mach Tools Manuf, 2002; 42:1441-1446.