

Optimization of Surface Finish and Material Removal Rate with Different Insert Nose Radius for Turning Operation on CNC Turning Center

Rishu Gupta¹, Ashutosh Diwedi²

¹PG student Mechanical Engineering Vindhya Institute of Technology and Science, Satna India,

²Asst. Professor and HOD, Department of Mechanical Engineering, Vindhya Institute of Technology and Science, Satna, India.

ABSTRACT— In this research work the effect of insert nose radius and machining parameters including cutting speed, feed rate and depth of cut on surface roughness and material removal rate (MRR) in a turning operation are investigated by using the Taguchi optimization method. A three level four parameter design of experiment, the signal-to-noise (S/N) ratio are employed to the study the performance characteristics in the turning of Aluminium Alloy 6061 using nose radius of 0.4, 0.8 and 1.2 mm carbide inserts on CNC turning centre. The conclusions revealed that the feed rate and nose radius were the most influential factors on the surface roughness and Material Removal Rate (MRR) in CNC turning process is greatly influenced by depth of cut followed by cutting speed. For simultaneous optimization of Surface roughness (R_a) and material removal rate (MRR) depth of cut is the most significant parameter affecting the performance followed by the nose radius.

KEYWORDS: Inserts, Taguchi, S/N ratio, Aluminium, MRR, Surface Roughness, Nose radius.

I. INTRODUCTION

Turning is the removal of metal from the outer diameter of a rotating cylindrical work piece. Turning is used to reduce the diameter of the work piece, usually to a specified dimension, and to produce a smooth finish on the metal. Turning is the machining operation that produces cylindrical parts. The three primary factors in any basic turning operation are speed, feed, and depth of cut. Other factors such as kind of material and type of tool have a large influence, of course, but these three are the ones the operator can change by adjusting the controls, right at the machine. Tool geometry parameters play an important role in determining the overall machining performance, including cutting forces, tool wear, surface finish, chip formation and chip breaking. Several angles are important when introducing the cutting tool's edge into a rotating work piece. These angles include the angle of inclination, rake angle, effective rake angle, lead or entry angle, and tool nose radius.

On the strength of the review of work done by previous researchers [1- 13], it is found that a considerable amount of work has been carried out by previous investigators for modeling, simulation and parametric optimization of surface properties of the product in turning operation. Issues related to tool life, tool wear, cutting forces have been addressed to. But a very little work has been found in uses of different 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; and ranks the parameters namely 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.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 6, June 2014

II. MATERIALS AND METHODS

A. CNC Turning Centre

ACE Designers Ltd. make CNC turning centre with FANUC Oi-mate-TD controller is used to carry out the experimentation.

Table 1 Specifications of CNC turning center

Max. Turning diameter	190 mm
Max. Turning length	200 mm
Chuck Size	135 mm
Spindle Speed	50- 4000 rpm
Spindle motor power	5.5 kW/ 3.7 kW

B. Selection of Cutting Tools

The cutting tool selected for present work is carbide inserts. The inserts (ANSI coding) used in present work are WNMG 331 RP (a), WNMG 332 RP (b) and WNMG 333 RP (c).

Table 2: The tool geometry of the inserts used

Insert	Shape	Clearance angle	Inscribed circle size	Thickness	Nose radius
WNMG 331 RP	Trigon	0°	9.5mm	5mm	0.4mm
WNMG 332 RP	Trigon	0°	9.5mm	5mm	0.8mm
WNMG 333 RP	Trigon	0°	9.5mm	5mm	1.2 mm

C. Selection of Work piece Material

The work piece material used for current work is Aluminium Alloy 6061 circular bars of diameter 25mm and length 50mm.

D. Process Parameters and Levels used in the Experiment

The machining process on CNC lathe is programmed by cutting speed, feed and depth of cut. The parameters and levels used in the experiment are shown in Table 3.

Table 3: Process parameters and levels

Levels	Variables			
	Cutting Speed, m/min (A)	Feed, mm/rev (B)	Depth of cut, mm (C)	Nose radius, mm (D)
Level 1	100	0.25	1	0.4
Level 2	150	0.3	1.5	0.8
Level 3	200	0.35	2	1.2

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 6, June 2014

E. Design Matrix

In the present work there are three levels and four parameters. According to Taguchi approach L9 orthogonal array has been selected. So, according to Taguchi L9 array design matrix of variables are formed.

Table 4: Design matrix of variables

Experiment	Cutting Speed, m/min (A)	Feed, mm/rev (B)	Depth of cut, mm (C)	Nose radius, mm (D)
1	100	0.25	1	0.4
2	100	0.3	1.5	0.8
3	100	0.35	2	1.2
4	150	0.25	1.5	1.2
5	150	0.3	2	0.4
6	150	0.35	1	0.8
7	200	0.25	2	0.8
8	200	0.3	1	1.2
9	200	0.35	1.5	0.4

III. RESULTS AND DISCUSSIONS

A. Material Removal Rate (MRR)

Initial and final weights of work pieces are noted using digital weighing machine. Machining time is also recorded. The density of the Aluminium is taken as $2.7 \times 10^{-3} \text{ g/mm}^3$.

B. Surface Roughness (R_a)

Surface Roughness measurement has been done using a portable stylus-type profilometer, Mitutoyo- Surf test SJ-201P/M. The evaluation length of 2.5 mm is used to measure response R_a value in μm .

C. Response Table

Response table for the experimental design matrix is shown in table 5.

Table 5: Response table of R_a and MRR

Exp.	A	B	C	D	R_a	MRR
1	100	0.25	1	0.4	3.25	10591.34
2	100	0.3	1.5	0.8	3.72	21369.38
3	100	0.35	2	1.2	4.65	27777.78
4	150	0.25	1.5	1.2	3.81	19779.39
5	150	0.3	2	0.4	4.11	31162.79

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 6, June 2014

6	150	0.35	1	0.8	3.97	16653.81
7	200	0.25	2	0.8	4.02	32354.2
8	200	0.3	1	1.2	4.35	16138.9
9	200	0.35	1.5	0.4	3.99	27204.3

D. Analysis of Single Response Stage

The optimal settings and the predicted optimal values for surface roughness and MRR are determined individually by Taguchi's approach. Table 8 shows these individual optimal values and its corresponding settings of the process parameters for the specified performance characteristics. It is observed that the feed is most significantly influences the R_a followed by nose radius. In case of MRR, depth of cut is the most significant parameter followed by cutting speed.

Table 6: Means of R_a at different levels

Levels	Mean value of R_a			
	Cutting Speed, m/min (A)	Feed, mm/rev (B)	Depth of cut, mm (C)	Nose radius, mm (D)
Level 1	3.87	3.69	3.65	3.78
Level 2	3.96	4.06	3.84	3.9
Level 3	4.12	4.2	4.26	4.27

Table 7: Means of MRR at different levels

Levels	Mean value of MRR			
	Cutting Speed, m/min (A)	Feed, mm/rev (B)	Depth of cut, mm (C)	Nose radius, mm (D)
Level 1	19912.83	20908.31	14461.35	23986.14
Level 2	22531.99	22890.35	22784.35	23459.13
Level 3	25232.46	23878.62	30431.58	21232.02

Table 8: Individual optimal values and corresponding setting of process parameters

Performance characteristics	Optimal parameter level	Optimum level
R_a (μm)	A1-B1-C1-D1	3.25
MRR (mm^3/min)	A3- B3-C3-D1	31256.94

F. Analysis of Multi- response stage

The S/N ratio considers both the mean and the variability. In the present work, a multi- response methodology based on Taguchi technique and Utility concept is used for optimizing the multi-responses (R_a and MRR). Taguchi proposed many different possible S/N ratios to obtain the optimum parameters setting. Two of them are selected for the present work. Those are, Smaller the better type S/N ratio for R_a

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 6, June 2014

$$[\eta_1] = -10 \log_{10} [R_a^2];$$

Larger the better S/N ratio for MRR

$$[\eta_2] = -10 \log_{10} \left[\frac{1}{MRR^2} \right]$$

From the utility concept, the multi-response S/N ratio of the overall utility value is given by

$$\eta_{obs} = W_1 \eta_1 + W_2 \eta_2$$

Where W_1 & W_2 are the weights assigned to the R_a and MRR. Assignment of weights to the performance characteristics are based on experience of engineers, customer's requirements and their priorities. In the present work equal importance is given for both R_a and MRR. Therefore W_1 & $W_2 = 0.5$.

The optimal combination of process parameters (A3-B3-C3-D1) for simultaneous optimization of Surface roughness (R_a) and material removal rate (MRR) is obtained by the mean values of the multi-response S/N ratio of the overall utility value are shown in Table 10. According to the Table 10 for the results of S/N ratio multiple performance characteristics, depth of cut is the most significant parameter affecting the performance followed by the nose radius. The percent contribution of the feed rate is lower and the cutting speed is much lower.

Table 9: Design matrix with multi- response S/N ratio

Exp.	A	B	C	D	η_1 for R_a	η_2 for MRR	η_{obs}
1	100	0.25	1	0.4	-10.24	80.49	35.13
2	100	0.3	1.5	0.8	-11.41	86.59	37.59
3	100	0.35	2	1.2	-13.35	88.87	37.76
4	150	0.25	1.5	1.2	-11.62	85.92	37.15
5	150	0.3	2	0.4	-12.28	89.87	38.79
6	150	0.35	1	0.8	-11.97	84.43	36.22
7	200	0.25	2	0.8	-12.08	90.19	39.06
8	200	0.3	1	1.2	-12.77	84.16	35.69
9	200	0.35	1.5	0.4	-12.02	88.69	38.34

Table 10: Mean value of η_{obs} at different levels

Levels	Mean value of η_{obs} for process parameters			
	Cutting speed (m/min)	Feed (mm/rev)	Depth of cut (mm)	Insert used
Level 1	36.83	37.11	35.68	37.42
Level 2	37.39	37.36	37.69	37.25
Level 3	37.69	37.44	38.54	36.87

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 6, June 2014

G. Interpretation of Plots

The data is plot and developed. These results are analyzed using S/N ratio for the purpose of identifying the significant factors which affect the surface roughness and material removal rate. The plots show the variation of individual response with the four parameters i.e. cutting speed, feed, depth of cut and nose radius separately. In the plots, the x-axis indicates the value of each process parameter at three level and y-axis the response value. Figure 1 shows the main effect plot for MRR. It is observed that the maximum MRR is obtained at the 200 m/min of cutting speed, 0.35mm/rev of feed, 2 mm depth of cut and 0.4 mm nose radius. Figure 2 shows the main effect plot for surface roughness. It is observed that the maximum surface finish or minimum roughness is obtained at the 100 m/min of cutting speed, 0.25mm/rev of feed, 1 mm depth of cut and 0.4 mm nose radius. Figure 3 shows the optimum levels of process parameters for the multi-response optimization are thus determined to be 200 m/min of cutting speed, 0.25mm/rev of feed, 2 mm depth of cut and 0.4 mm nose radius.

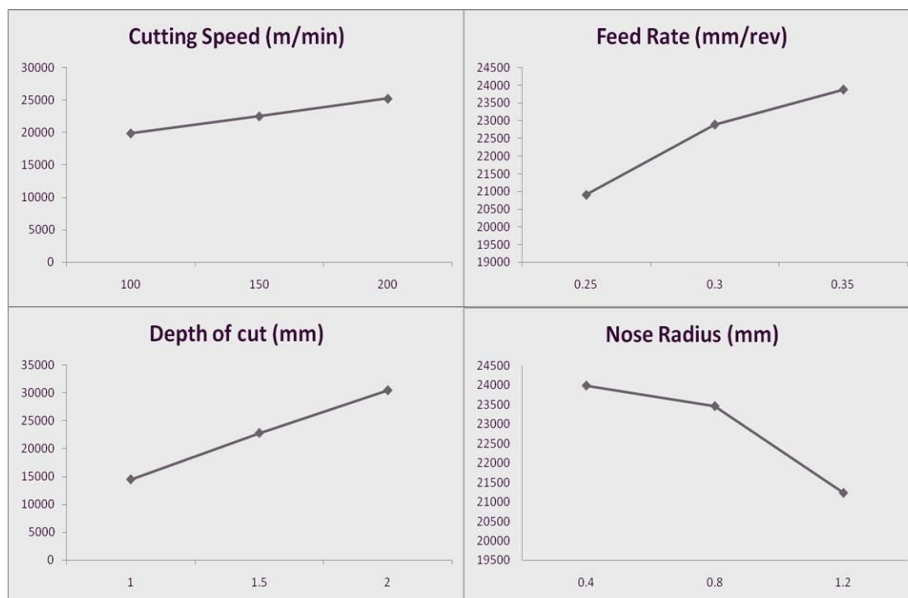


Fig. 1: Response Graph for MRR

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 6, June 2014

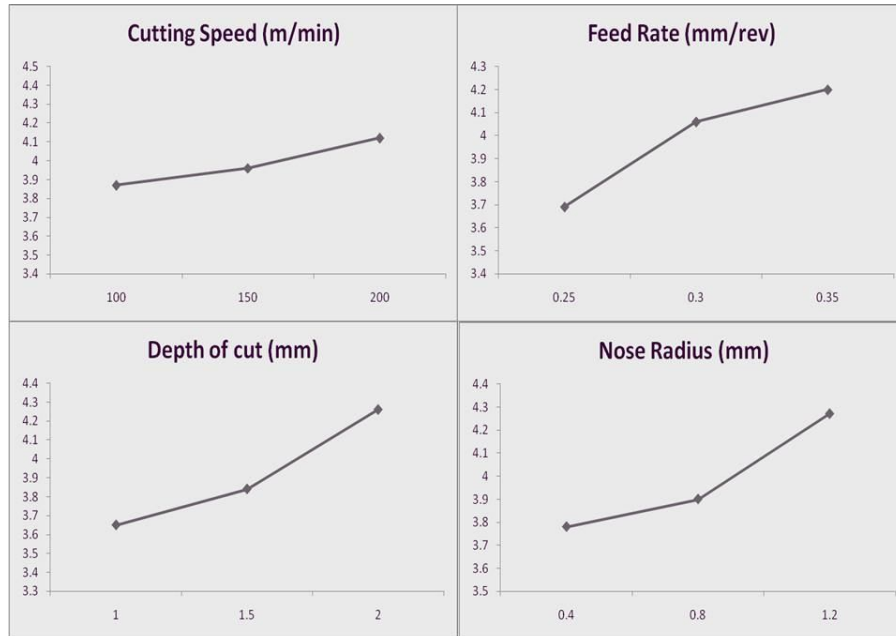


Fig. 2: Response Graph for R_a

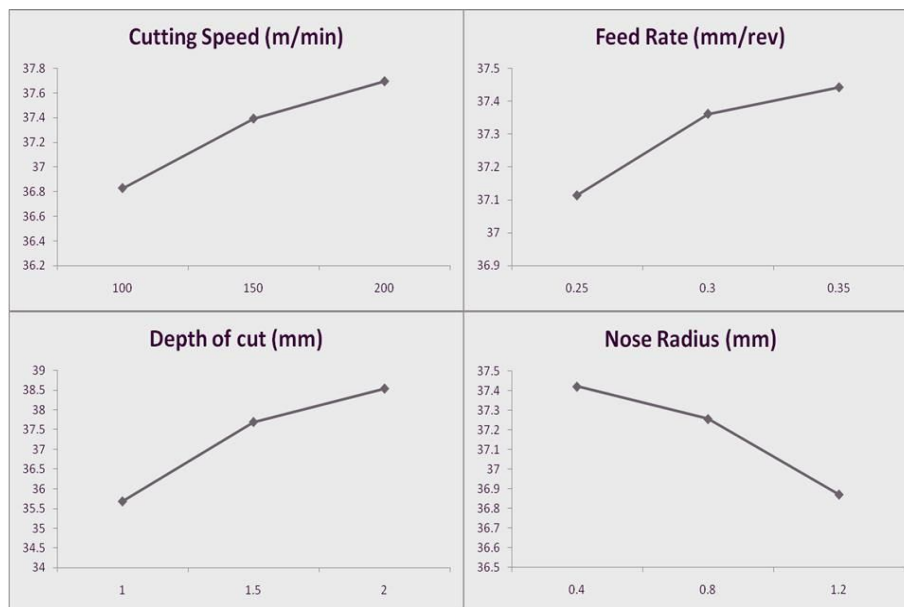


Fig. 3: Multi- Response S/N Ratio Graph

IV. CONCLUSIONS

Turning tests were performed on Aluminium Alloy 6061 work piece using three different carbide insert of varying nose radius. The influences of cutting speed, feed rate, depth of cut and nose radius were investigated on the machined surface roughness and Material Removal Rate (MRR). Based on the results obtained, the following conclusions have been drawn:

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 6, June 2014

- The analysis of the experimental observations highlights that MRR in CNC turning process is greatly influenced by depth of cut followed by cutting speed.
- It is observed that the feed is most significantly influences the R_a followed by nose radius.
- For simultaneous optimization of Surface roughness (R_a) and material removal rate (MRR) depth of cut is the most significant parameter affecting the performance followed by the nose radius.

REFERENCES

- [1] Feng, C.X. and Wang X, Development of empirical models for surface roughness prediction in finish 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] Süleyman Neşeli, Süleyman Yıldız and Erol Türkeş; Optimization of tool geometry parameters for turning operations based on the response surface methodology; Measurement; Volume 44, Issue 3, March 2011, Pages 580–587
- [9] Ahmet Hascalik and Ulas Cavdas; Optimization of turning parameters for surface roughness and tool life based on the Taguchi method; The International Journal of Advanced Manufacturing Technology; September 2008, Volume 38, Issue 9-10, pp 896-903
- [10] Chong-Jyh Tzeng, Yu-Hsin Lin, Yung-Kuang Yang and Ming-Chang Jeng; Optimization of turning operations with multiple performance characteristics using the Taguchi method and Grey relational analysis; Journal of Materials Processing Technology; Volume 209, Issue 6, 19 March 2009, Pages 2753–2759
- [11] Anil Gupta, Hari Singh and Aman Aggarwal; Taguchi-fuzzy multi output optimization (MOO) in high speed CNC turning of AISI P-20 tool steel; Expert Systems with Applications; Volume 38, Issue 6, June 2011, Pages 6822–6828
- [12] Raju Shrihari Pawade and Suhas S. Joshi; Multi-objective optimization of surface roughness and cutting forces in high-speed turning of Inconel 718 using Taguchi grey relational analysis (TGRA); The International Journal of Advanced Manufacturing Technology; September 2011, Volume 56, Issue 1-4, pp 47-62
- [13] M. Kaladhar, K. Venkata Subbaiah, Ch. Srinivasa Rao and K. Narayana Rao; Optimization of process parameters in turning of AISI202 austenitic stainless steel; Asian Research Publishing Network (ARPN)