International Journal of Innovative Research in Advanced Engineering (IJIRAE) ISSN: 2349-2763
Issue 03, Volume 3 (March 2016) www.ijirae.com

EXPERIMENTAL STUDY OF TURNING OPERATION AND OPTIMIZATION OF MRR AND SURFACE ROUGHNESS USING TAGUCHI METHOD

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Abstract— In this research work turning operation is performed on AISI 1020 mild steel. Here we conducted experiments by taking Cutting Speed, Feed Rate & Depth of cut as process parameters and got the optimized value of MRR & SR. An L9 orthogonal array, the signal-to-noise (S/N) ratio are employed to the study the performance characteristics in the turning using WNMG332RP carbide insert with a nose radius of 0.8mm. Taguchi method is used to optimize surface roughness and material removal rate (MRR) during machining operation on CNC turning. The experimental result shows that on increasing depth of cut and feed the combined S/N ratio increases while on increasing cutting speed the combined S/N ratio decreases. It results that cutting speed is most significantly influences the Surface roughness followed by feed and in case of MRR, depth of cut is the most significant parameter followed by cutting speed .While the combination of both is most significantly affected by the depth of cut followed by the feed.

Keywords— Insert, Taguchi, S/N ratio, Mild steel, MRR, Surface Roughness.

I. INTRODUCTION

Surface roughness and material removal rate prediction plays a significant role in machining industry for proper planning and control of machining parameters and optimization of cutting conditions. Now-a-days increasing the productivity and quality of the machined parts are the main challenges of metal cutting industry during turning processes. Optimization in turning processes is considered a vital role for continual improvement of output quality in product and processes include modelling of input-output and in process parameters relationship and determination of optimal cutting conditions. The effects of process parameters on tool life on turning process and the subsequent optimal settings of parameters are accomplished using Taguchi`s method. Surface roughness has become the most significant technical requirement and it is an index of product quality. In order to improve the tribological properties, fatigue strength, corrosion resistance and aesthetic appeal of the product, a reasonably good surface finish is desired.

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.

As a result of exhaustive review of work done by previous researchers [1-20], it is found that a very little work has been found in use of AISI 1020 mild steel on the three cutting parameters i.e. speed, feed and depth of cut.

The 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 through S/N ratio. MRR of a turned product along with surface finish of work piece have been optimized.

II. MATERIALS AND METHOD

A. *CNC Turning Center*

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

TABLE I
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 used in present work is WNMG 332 RP (ANSI coding).

The tool geometry of the insert is as follows:

Insert WNMG 332 RP – Trigon Shape, Clearance angle 0°, Inscribed Circle size- 9.5mm, Thickness- 5mm, Nose radius- 0.8mm.

C. Selection of Work piece Material

The work piece material used for current work is AISI 1020 Mild Steel circular bars (ϕ 25mm x 110mm).

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 II.

TABLE II
PROCESS PARAMETERS AND LEVELS

LEVELS	VARIABLES		
	FEED MM/REV (A)	DEPTH OF CUT MM (B)	CUTTING SPEED M/MIN (C)
LEVEL 1	0.1	0.5	75
LEVEL 2	0.2	0.75	125
LEVEL 3	0.3	1.0	175

E. Design Matrix

In the present work there are three levels and three factors. According to Taguchi approach L9 has been selected. So, according to Taguchi L9 array design matrix of variables are formed. The array has been made with the help of MINITAB17.

TABLE III
DESIGN MATRIX OF VARIABLES

EXPERIMENT	FEED (MM/REV) A	DOC (MM) B	CUTTING SPEED (M/MIN) C
1	0.1	0.5	75
2	0.1	0.75	125
3	0.1	1.0	175
4	0.2	0.5	125
5	0.2	0.75	175
6	0.2	1.0	75
7	0.3	0.5	175
8	0.3	0.75	75
9	0.3	1.0	125

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. Following equations are used to calculate the response Material Removal Rate (MRR):

$$MRR(mm^3/min) = \frac{[\text{Initial Weight of workpiece(gm)} - \text{Final Weight of workpiece(gm)}]}{\text{Density}(gm/mm^3) \times \text{Machining Time (min)}}$$

The density of the mild steel is taken as 7.87 x 10^{-3} g/mm^3.

B. Surface Roughness (R_a)

Roughness measurement has been done using a stylus type Taylor-Hobson-Talysurf equipment. The evaluation length of 5.6 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 IV.

TABLE IV
RESPONSE TABLE OF R_a AND MRR

EXP.	A	B	C	RA	MRR
1	0.1	0.5	75	1.464	1355.358
2	0.1	0.75	125	2.062	3815.76
3	0.1	1.0	175	2.972	6496.546
4	0.2	0.5	125	3.284	3494.282
5	0.2	0.75	175	4.264	6873.998
6	0.2	1.0	75	2.220	7115.629
7	0.3	0.5	175	3.662	5476.931
8	0.3	0.75	75	2.549	7637.775
9	0.3	1.0	125	3.586	12228.79

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 VII shows these individual optimal values and its corresponding settings of the process parameters for the specified performance characteristics.

TABLE V
MEANS OF R_a AT DIFFERENT LEVELS

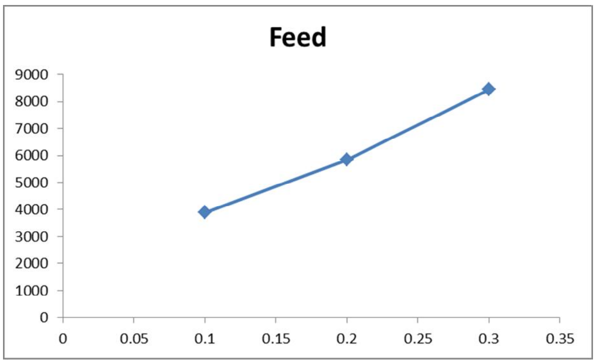
LEVELS	MEAN VALUE OF R_A		
	FEED (MM/REV)A	DOC (MM)B	CUTTING SPEED (M/MIN)C
LEVEL 1	2.166233	2.8036	2.0775
LEVEL 2	3.2559	2.923667	2.977467
LEVEL 3	3.265933	2.926133	3.598433

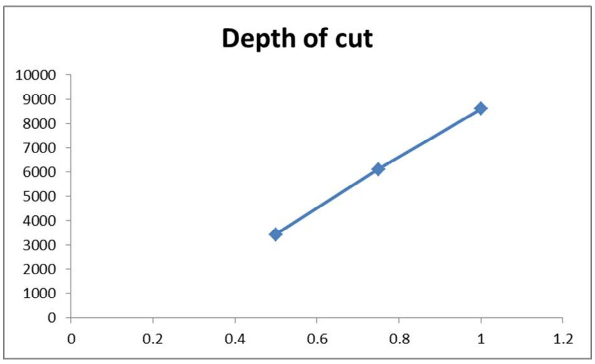
TABLE VI
MEANS OF MRR AT DIFFERENT LEVELS

LEVELS	MEAN VALUE OF MRR		
	FEED (MM/REV)A	DOC (MM)B	CUTTING SPEED (M/MIN)C
LEVEL 1	3889.221	3442.19	5369.587
LEVEL 2	5827.97	6109.177	6512.945
LEVEL 3	8447.833	8613.656	6282.492

TABLE VII
INDIVIDUAL OPTIMAL VALUES AND CORRESPONDING SETTING OF PROCESS PARAMETERS

PERFORMANCE CHARACTERISTICS	OPTIMAL PARAMETER LEVEL	OPTIMUM LEVEL
R_A (μM)	A1-B1-C1	1.464
MRR (MM^3/MIN)	A3-B3-C2	12228.79





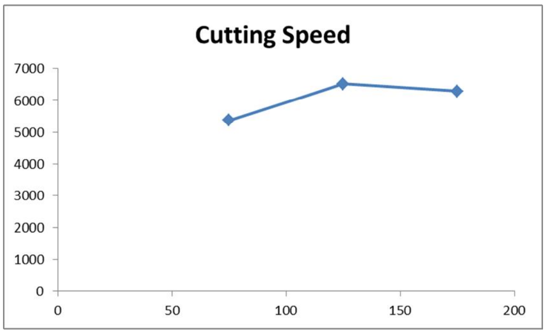


Fig. 2 Response Graph for MRR

ANALYSIS OF PLOT FOR MRR:

It is observed that the maximum MRR is obtained at the 125 m/min of cutting speed, 0.3 mm/rev of feed and 1 mm depth of cut. The plot shows that on increasing the depth of cut and feed, the MRR further increases and on increasing cutting speed, the MRR increases initially and then decreases.

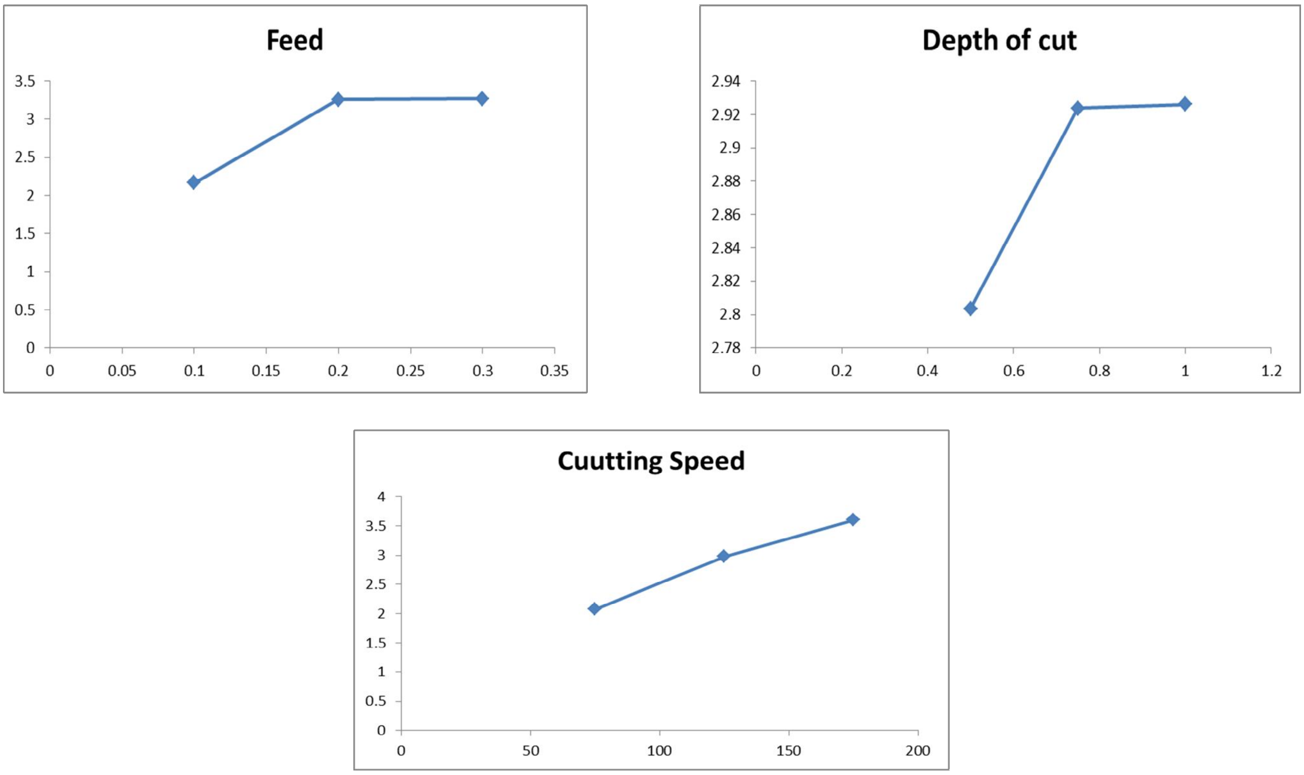


Fig. 1 Response Graph for R_a

ANALYSIS OF PLOT FOR SURFACE ROUGHNESS:

It is observed that the minimum surface roughness is obtained at the 75 m/min of cutting speed, 0.1 mm/rev of feed and 0.5 mm depth of cut. The plot shows that on increasing the cutting sped, depth of cut and feed, the Surface roughness further increases.

E. 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 (Ra 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

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

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 Ra and MRR. Therefore W_1 & W_2 = 0.5.

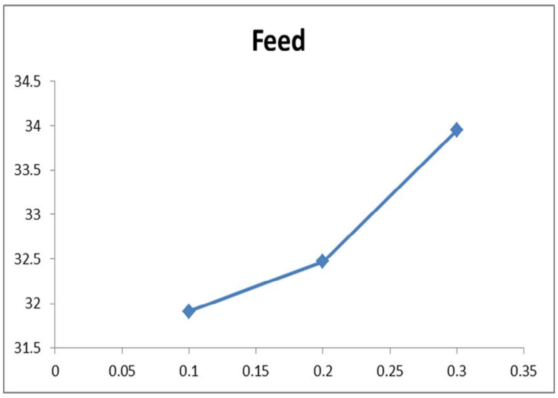
The optimal combination of process parameters (A3-B3-C2) for simultaneous optimization of Surface roughness (R_a) and material removal rate (MRR) is obtained by the mean values of the multi-response S/N ratio of the overall utility value are shown in Table IX. According to the Table IX for the results of S/N ratio multiple performance characteristics, depth of cut is the most significant parameter affecting the performance followed by the cutting speed.

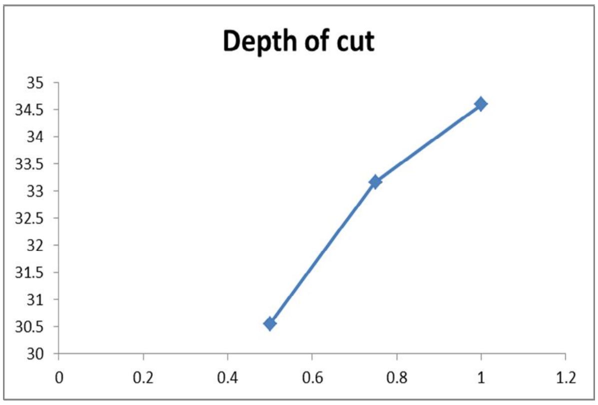
TABLE VIII
DESIGN MATRIX WITH MULTI- RESPONSE S/N RATIO

Exp.	A	B	C	η_1 for R_A	η_2 for MRR	ηobs
1	0.1	0.5	75	-3.31082	62.64108	29.66513
2	0.1	0.75	125	-6.28577	71.631621	32.67292
3	0.1	1.0	175	-9.46302	76.253651	33.39531
4	0.2	0.5	125	-10.3286	70.867159	30.26928
5	0.2	0.75	175	-12.5963	76.744187	32.07392
6	0.2	1.0	75	-6.9251	77.044266	35.05958
7	0.3	0.5	175	-11.2758	74.770746	31.74748
8	0.3	0.75	75	-8.1274	77.659337	34.76597
9	0.3	1.0	125	-11.0927	81.747672	35.32749

TABLE IX
MEAN VALUE OF η_{obs} AT DIFFERENT LEVELS

Levels	Mean value of ηobs		
	Feed (mm/rev)A	DOC (mm)B	Cutting Speed (m/min)C
Level 1	31.91112	30.56063	33.16356
Level 2	32.4676	33.17094	32.75657
Level 3	33.94698	34.59413	32.40557





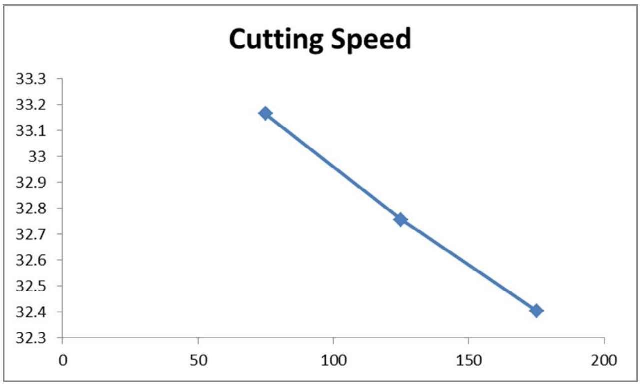


Fig. 3 Multi-Response S/N Ratio Graph

ANALYSIS OF PLOT FOR MULTI RESPONSE:

The graph shows the optimum levels of process parameters for the multi-response optimization are thus determined to be 125 m/min of cutting speed, 0.3 mm/rev of feed and 1 mm depth of cut. The plot shows that on increasing depth of cut and feed the combined S/N ratio increases while on increasing cutting speed the combined S/N ratio decreases.

IV. CONCLUSIONS

Turning tests were performed on AISI 1020 mild steel work piece using carbide insert 0.8 mm nose radius. The influences of cutting speed, feed rate and depth of were investigated on the machined surface roughness and Material Removal Rate (MRR). Based on the results obtained, the following conclusions have been drawn:

- The analysis of the experimental observations highlights that MRR in CNC turning process is greatly influenced by depth of cut followed by feed.
- It is observed that the cutting speed is most significantly influences the R_a followed by the feed.
- 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 feed.

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