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Comparative Performance Study of Turning Operation on CNC Turning Centre

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***Abstract:** In this research work we analyzed the effect of machining parameters on surface roughness and material removal rate (MRR) in a turning operation and get the optimized result by using the Taguchi method. The experimental studies are conducted under varying cutting parameters including cutting speed, feed rate, depth of cut and WNMG332RP, TNMG332RP, and SNMG432RP carbide inserts on CNC turning centre. We selected L9 orthogonal array to perform experiments based on the parameters and levels. The signal-to-noise (S/N) ratio is employed to the study the performance characteristics in the turning of Mild steel. The conclusions revealed that the feed rate, cutting speed, depth of cut and insert have a great impact on MRR & surface roughness.*

***Keywords:** CNC Turning Centre, AISI 1045 Mild Steel work piece, Cutting Speed, Feed Rate, Depth of Cut, Inserts, Taguchi, Minitab 17, S/N Ratio, MRR, Surface Roughness.*

INTRODUCTION:

Cutting Speed, Feed Rate, Depth of cut & Tool geometry are the parameters which play an important role in determining the overall machining performance MRR & Surface finish. Over the past few decades, many investigations have been made to study the important effects of tool geometry along with cutting speed, feed rate & depth of cut, on machining performance. It is well known that these are the major factors which influence the machining performance like MRR & Surface finish and have been used in various mathematical models of machining process. on the strength of the exhaustive review of work done by previous researchers [1- 13], it is found that a very little work has been done in use of Cutting Speed, Feed Rate, Depth of cut & Tool geometry as the parameters for optimizing the machining performance like MRR & Surface finish.

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

MATERIAL AND METHODS

CNC TURNING CENTER

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

SELECTION OF CUTTING TOOLS

The cutting tool selected for present work is carbide inserts. The inserts (ANSI coding) used in present work are “a”-WNMG 332 RP, “b”-TNMG332 RP and “c”-SNMG432 RP.

The tool geometry of the inserts is as follows:

- *Insert WNMG 332 RP – Trigonal Shape, Clearance angle 0°, Inscribed Circle size- 9.5mm, Thickness- 5mm.*
- *Insert TNMG 332 RP – Triangular Shape, Clearance angle 0°, Inscribed Circle size- 9.5mm, Thickness- 5mm.*
- *Insert SNMG 333 RP – Hexagonal Shape, Clearance angle 0°, Inscribed Circle size- 9.5mm, Thickness- 5mm.*

SELECTION OF WORK PIECE MATERIAL

The work piece material used for current work is AISI 1045 Mild Steel circular bars (ϕ 25mm x 50mm).

PROCESS PARAMETERS AND LEVELS USED IN THE EXPERIMENT

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

TABLE-2: PROCESS PARAMETERS AND LEVELS

Levels	Variables			
	Cutting Speed, m/min (A)	Feed, mm/rev (B)	Depth of cut, mm (C)	Insert used (D)
Level 1	100	0.25	0.5	A
Level 2	150	0.3	0.75	B
Level 3	200	0.35	1	C

DESIGN MATRIX

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

TABLE-3: DESIGN MATRIX OF VARIABLES

Experiment	Cutting Speed, m/min (A)	Feed, mm/rev (B)	Depth of cut, mm (C)	Insert, (D)
1	100	0.25	0.5	A
2	100	0.3	0.75	B
3	100	0.35	1	C
4	150	0.25	0.75	C
5	150	0.3	1	A
6	150	0.35	0.5	B
7	200	0.25	1	B
8	200	0.3	0.5	C
9	200	0.35	0.75	A

RESULTS AND DISCUSSIONS

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):

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

The density of the mild steel is taken as 7.79345×10^{-3} g/mm^3.

SURFACE ROUGHNESS (R_{a})

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

RESPONSE TABLE

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

TABLE-4: RESPONSE TABLE OF R_A AND MRR

Exp.	A	B	C	D	R_A	MRR
1	100	0.25	0.5	A	2.45	2885.8218
2	100	0.3	0.75	B	2.85	7699.7387
3	100	0.35	1	C	3.57	11132.253
4	150	0.25	0.75	C	3.45	10029.313

5	150	0.3	1	A	3.58	10699.71
6	150	0.35	0.5	B	3.25	8534.1583
7	200	0.25	1	B	3.88	12871.544
8	200	0.3	0.5	C	3.75	8784.0177
9	200	0.35	0.75	A	3.876	11223.662

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

TABLE-5: MEANS OF RA AT DIFFERENT LEVELS FOR MILD STEEL

LEVELS	MEAN VALUE OF R_A			
	CUTTING SPEED, M/MIN (A)	FEED, MM/REV (B)	DEPTH OF CUT, MM (C)	INSERT, MM (D)
LEVEL 1	2.9566667	3.26	3.15	3.302
LEVEL 2	3.4266667	3.3933333	3.392	3.326667
LEVEL 3	3.8353333	3.5653333	3.6766667	3.59

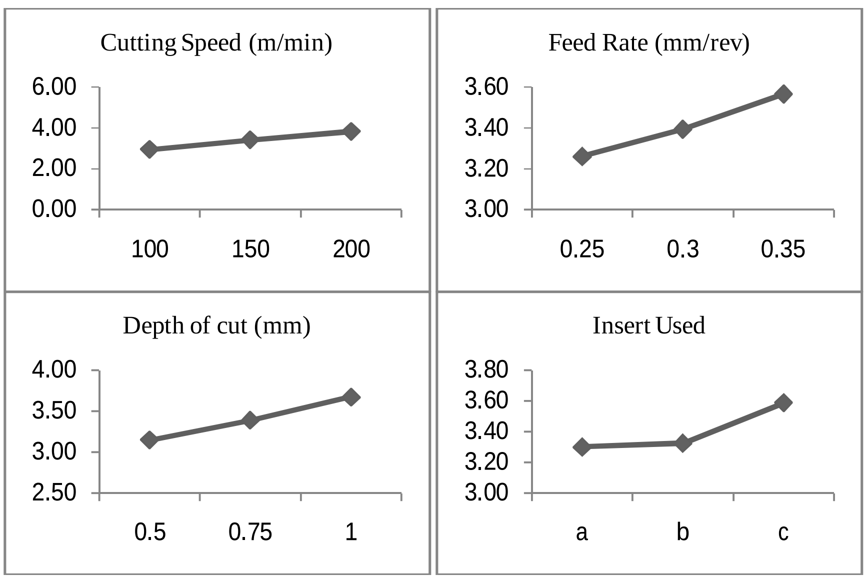

FIG. 1: RESPONSE GRAPH FOR SURFACE ROUGHNESS

INTERPRETATION OF PLOTS FOR SURFACE ROUGHNESS:

- *BASED ON CUTTING SPEED: Surface roughness increases with the increase in Cutting speed.*
- *BASED ON FEED RATE: With the increase in feed rate, the value of Surface roughness increases.*
- *BASED ON DEPTH OF CUT: As we increase depth of cut from 0.5 mm to 0.75 mm, the value of surface roughness increases and with the further increase in depth of cut from 0.75 mm to 1 mm, surface roughness also increases.*
- *BASED ON INSERTS: when we use insert "a", the value of surface roughness is low. At insert "b", surface roughness is more. And at insert "c" we get the max. Surface roughness i.e. lowest surface finish.*

TABLE-6: MEANS OF MRR AT DIFFERENT LEVELS FOR MILD STEEL

LEVELS	MEAN VALUE OF MRR			
	CUTTING SPEED, M/MIN (A)	FEED, MM/REV (B)	DEPTH OF CUT, MM (C)	INSERT, MM (D)
LEVEL 1	7239.271	8595.559	6734.7	8270

LEVEL 2	9754.394	9061.156	9650.9	9702
LEVEL 3	10959.74	10296.69	11568	9982

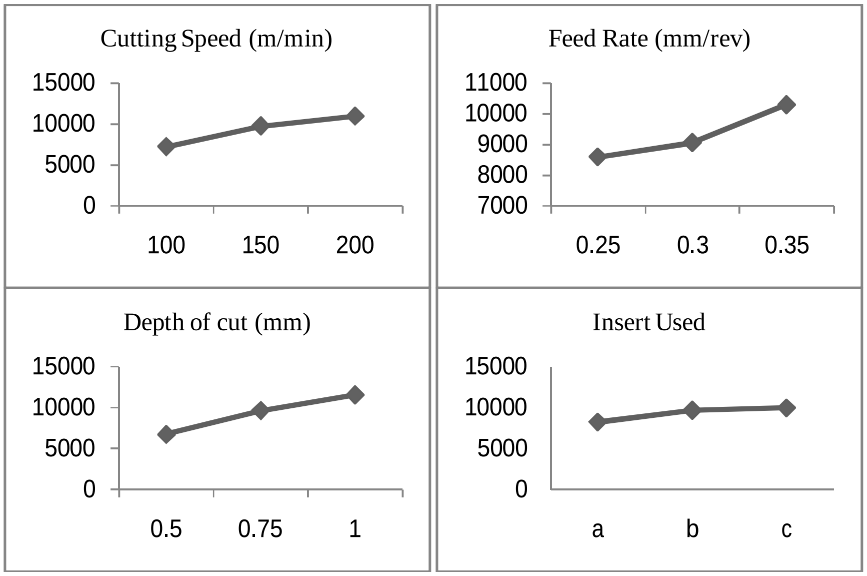

FIG. 2: RESPONSE GRAPH FOR MRR

INTERPRETATION OF PLOTS FOR MRR:

- *BASED ON CUTTING SPEED: MRR increases with the increase in Cutting speed.*
- *BASED ON FEED RATE: With the increase in feed rate, the value of MRR increases.*
- *BASED ON DEPTH OF CUT: With the increase in depth of cut, the value of MRR increases.*
- *BASED ON INSERTS: when we use insert "a", the value of MRR is low. At insert "b", MRR is more. And at insert "c" we get the max. MRR.*

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 best combination for process parameters for simultaneous optimization of Material removal rate (MRR), & Surface roughness (R_a) is obtained by the mean values of the multi-response S/N ratio shown in Table.

TABLE-7: DESIGN MATRIX WITH MULTI-RESPONSE S/N RATIO FOR MILD STEEL

Exp.	A	B	C	D	η_1 for R_a	η_2 for MRR	η_{obs}
1	100	0.25	0.5	A	-7.783321687	69.20539029	30.7110343
2	100	0.3	0.75	B	-9.0968972	77.72951972	34.3163113
3	100	0.35	1	C	-11.05336432	80.93166172	34.9391487
4	150	0.25	0.75	C	-10.7563819	80.02542328	34.6345207
5	150	0.3	1	A	-11.07766053	80.58744045	34.75489
6	150	0.35	0.5	B	-10.23766722	78.62321385	34.1927733
7	200	0.25	1	B	-11.77663451	82.19261302	35.2079893
8	200	0.3	0.5	C	-11.48062535	78.873864	33.6966193
9	200	0.35	0.75	A	-11.76767537	81.0026916	34.6175081

TABLE-8: MEAN VALUES OF H_{OBS} AT DIFFERENT LEVELS

Levels	Mean Value of H_{OBS} for Process Parameters			
	Cutting speed	Feed	DOC	Insert
Level 1	33.322165	33.51784808	32.86680898	33.3611441
Level 2	34.527395	34.25594018	34.52278002	34.5723579
Level 3	34.507372	34.58314338	34.96734264	34.4234296

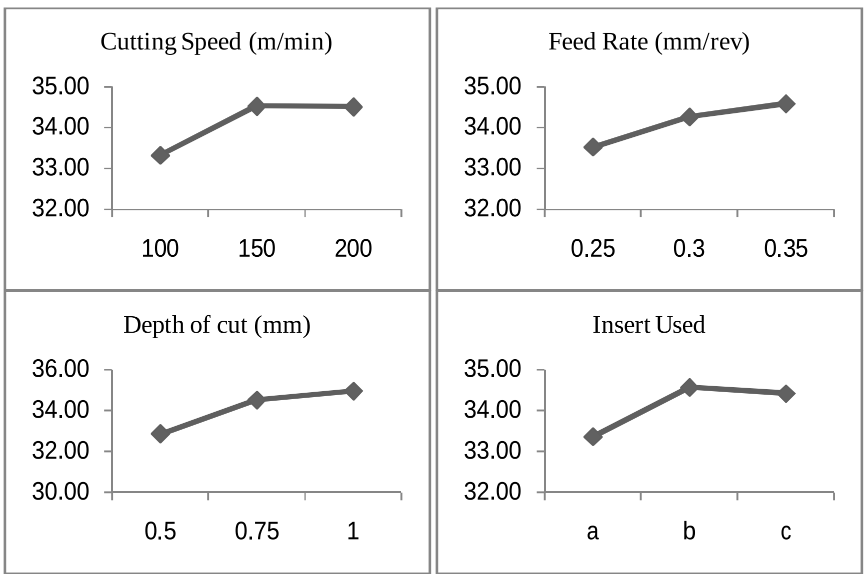

FIG. 3: MULTI-RESPONSE S/N RATIO GRAPH

INTERPRETATION OF PLOTS

The multi response S/N ratio graphs shows the optimal level of MRR, & Ra with the variation in parameters i.e. cutting speed, Feed rate, Depth of cut & Insert used. As there are four process parameters, so there are four graphs as given:

BASED ON CUTTING SPEED

This graph is a plot between the process parameter i.e. Cutting speed on x-axis and the optimum values obtained from Multi-response table on the y-axis. This graph gives the combined result for MRR & Surface Roughness. As the cutting speed is increased from its initial value 100 m/min., the multi response value for MRR & Ra also increases. But with the further increase in cutting speed, the multi response value for MRR & Ra also decreases. We get the best optimum value for MRR & Ra at cutting speed 150m/min.

BASED ON FEED RATE

This graph is a plot between the process parameter i.e. Feed rate on x-axis and the optimum values obtained from Multi-response table on the y-axis. This graph gives the combined result for MRR & Surface Roughness. As the feed rate is increased from its initial value, the multi response value for MRR & Ra also increases.

With the further increase in feed rate from 0.30 mm/rev. to 0.35 mm/rev., the value obtained from multi response also increases. We get the best optimum value for MRR & Ra at feed rate 0.35 mm/rev.

BASED ON DEPTH OF CUT:
This graph is a plot between Depth of cut on x-axis and the optimum values obtained from Multi-response table on the y-axis. This graph gives the combined result for MRR & Surface Roughness. With the increase in depth of cut, the multi response value for MRR & Ra also increases.

BASED ON INSERTS:
This graph is a plot between Inserts used on x-axis and the optimum values obtained from Multi-response table on the y-axis. This graph gives the combined result for MRR & Surface Roughness. When we use insert “a”, the multi response value is low. At insert “b”, the multi response value is more. And at insert “c” the multi response value for MRR & Ra decreases. So we get the optimum level on insert “b”.

CONCLUSION

A set of experiments are performed on AISI 1045 Mild steel work pieces on CNC turning centre lathe. The experimental studies are conducted by taking Cutting Speed, Feed Rate, Depth of cut & Tool geometry as process parameters, which play an important role in determining the overall machining performance MRR & Surface finish. Based on the results obtained, the following conclusions have been drawn:

- The analysis of the experimental observations highlights that with the increase in cutting speed, depth of cut and feed rate, the value of surface roughness increases. At insert “c” we get the max. Surface roughness i.e. lowest surface finish and at insert “a” we get the minimum surface roughness i.e. max. Surface finish.
- The value of MRR increases with the increase in cutting speed, feed rate and depth of cut. At insert “c” we get the max. MRR.
- For getting the optimum level for MRR & Ra, cutting speed should be medium i.e. 150 m/min., feed rate should be high i.e. 0.35 mm/rev., Depth of cut should be high i.e. 1 mm, and insert of type “b” should be used.

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