ENGINEERING RESEARCH JOURNAL (ERJ)
Vol. 1, No. 39 Jan. 2019, pp. 32-38.
Journal Homepage: www.feng.bu.edu.eg

Effect Of Cutting Tool Coating And Cutting Parameters On Surface Quality And Material Removal Rate In Turning Of Stainless Steel 304

A.N. Aladwani , S.S.Mohamed , T. A.Khalil , A. M.Gaafer

Mechanical Engineering Department, Shoubra Faculty of Engineering, Benha University, Cairo, Egypt.

Abstract. Prediction of surface Quality and metal removal rate (MRR) play an important role for proper control of machining parameters during turning operation. The selection of proper cutting tool is considered one of the most factors affecting the quality of machined surface. Therefore, the aim of this work is to investigate the effect of type and coating material of cutting tool on surface roughness and roundness error in turning operation of stainless-steel 304. The experiments were conducted using cutting speed, feed rate, type of tool coating and depth of cut as process parameters. Taguchi orthogonal array L27 and ANOVA were employed to plan and analysis the experimental results. Signal to nose ratios were used to analysis the performance characteristics in turning operation. The results showed that cutting speed is the most significant factor on surface roughness, followed by tool coating. Cutting speed is the most significant factor on metal removal rate followed by depth of cut. Cutting speed is the most significant factor on roundness error followed by the type of tool coating.

Keywords : ANOVA, Taguchi, Surface roughness ,Roundness, Material removal rate.

1. INTRODUCTION

Nowadays manufacturing industries are concerned with dimensional accuracy and

Surface finish. The quality of manufactured products must be controlled in all manufacturing stages to reduce the number of rejected items and then reducing the total production cost. Therefore, the proper selection, prediction and optimization of cut of ting tool and process parameters in machining processes have be important target the research workers in the machining field. Sahoo [1] was investigated the parametric analysis and optimization of turning operation by using Taguchi approach of L9 orthogonal array. It has been found that spindle speed is the most influence parameter on surface roughness, followed by feed rate. The same technique was used on different materials and the same results were observed [2, 3]. Dave et al[4] studied the effect of machining conditions on metal removal rate and surface roughness during CNC turning of different materials using TiN coated cutting tools with the aid of Taguchi method and ANOVA. They found that spindle speed was the most significant parameter on surface roughness, material removal rate depth of cut followed by feed rate. A respectively similar results were also reported [5, 6, 7, 8].

Mishra and Gangele[9] applied Taguchi method in optimization of tool flank wear width in turning operation of AISI (1045) steel. They found that depth of cut was most significant parameters on tool flank wear, followed by spindle speed. The effects of cutting tool geometry and processing parameters on the surface roughness of AISI 1030 stainless steel by using Taguchi method. It was found that the nose radius was most significant parameter on surface roughness and material removal rate, followed by cutting speed and depth of cut respectively [10, 11].

From the above discussion, it is obvious that the machined surfaces are influenced by several quantitative and qualitative factors. Therefore the effort must be continue in this field. The aim of this research is to deduce the machining parameters such as, cutting speed, feed rate and depth of cut, in addition to tool material and type of coating material which produce better work piece surface machined by turning operation.

2. Experimental Works

2.1 workpiece material

In this work, the turning process was performed on cylindrical work pieces of dimensions Ø25 mm x 100 mm (length) made from stainless steel 304. The selection of this material as a work piece material, because it has excellent toughness, corrosion and oxidation resistance and ease of fabrication. Therefore it is used for a wide variety of applications such as food industry, pipelines, valves and milk trucks cars etc. The chemical composition and mechanical properties are presented in tables 1 and 2 respectively.

Table .1 Chemical composition of SS 304

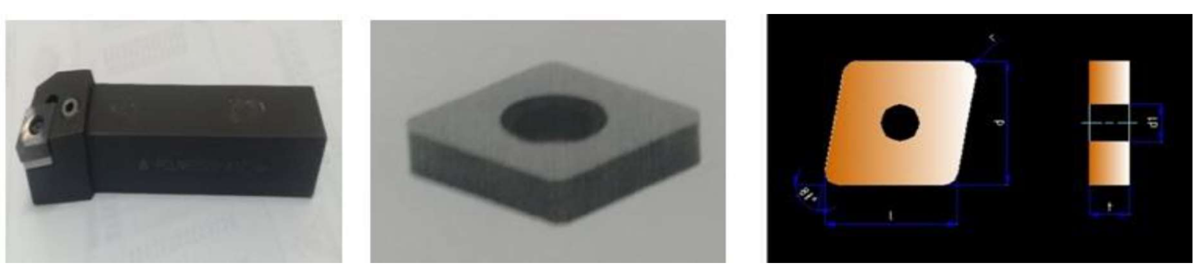
GRADE	C	Cr	Ni	Mn	Si	S	P	CU	Fe
304	0.08	17.5	8.36	1.09	0.45	0.03	0.03	0.7	balance

Table 2. Mechanical properties of SS 304

Grade	Tensile Strength (MPa)	Yield strength(MPa)	Elongation (%)	Brignell Hardness (HB)
304	515	205	40	201

2.2 Tool Material and Machine Specifications:

In this work different coated cutting tool were be used in turning process, the tools have the same specification, but have different properties like as TiAlN coating and ultra-fine grains substrate adopted, high chipping and welding resistance for stable machine in case of (PC9030, PVD coating) and Stable machinability with chipping resistance, fracture resistance and welding resistance, Ultra-fine substrate with high toughness and new ACiN layer in case of (NC5330, CVD coating). Tool holder and insert geometry is shown in figure (1 a, b and c), where the types of coating and specification were indicated in table3.



(a) Tool holder (b) Carbide insert (c) dimensions of carbide insert (dim. in mm)

Figure (1)

Table.3 the specification of cutting tool material

Tool type	Design	Coated	I	D	T	R	D1	F n	Ap
CNMG-VM	120408-VM	PC9030 PVD coating	12	12.7	4.76	0.8	5.16	Up to 0.50	Up to 5
CNMG-VM	120408-VM	PC5400 PVD coating	12	12.7	4.76	0.8	5.16	Up to 0.50	Up to 5
CNMG-VM	120408-VM	NC5330 CVD coating	12	12.7	4.76	0.8	5.16	Up to 0.50	Up to 5

The selection of the insert tip was chosen according to KORLOY manufacturing catalog according to work piece material, the range of speed (up to 2133 mm/sec), range of feed (up to 0.40 mm/rev), range of depth of cut (up to 3.50 mm) according to tool material. The turning experiments were carried out using a conventional center lathe machine. machine (length between chuck center to dead center 750 mm, maximum Diameter 420 mm, power 5 HP, speed up to 1250 rpm, feed motion Range (up to 1.30 mm). The work-piece was clamped between two centers (dog and live center).

2.3 Measurement devices

The surface roughness parameter (R_a) of the specimens was measured with Surftest SJ-310 instrument and the roundness tester Talyrond 73- taylor hobson, S/no. 112/2802-0123, L.R = 0.01 µm.The uncertainty (U) evaluation is carried out in accordance with the JCGM 100:2008(U = $\pm$ 2.0 µm.).U is the expanded uncertainty using a coverage factor K = 2, providing a level of confidence of approximately 95 %.

All equipment used for measurement are traceable to gauge blocks which were calibrated by optical interferometer at KRISS traceable to SI units.

3.Design of experiments:

Design of experiments (DOE) based Taguchi method can be used for reducing the number of experiments. Taguchi has suggested various orthogonal arrays (OA) for performing the experiments. The OA is selected on the basis of the total degree of freedom (DOF) of all the input parameters. So an L27 OA having 26 (= 27-1) DOF has been selected for conducting the experiments for this work.In the presented work, the turning process parameters and thire levels are indicated in table 4.

Table 4. The turning process parameters levels

Parameter	Unite	Level 1	Level 2	Level 3
Tool Coating (A)	-	PC (9030)	PC(5400)	NC (5330)
Cutting speed (B)	(mm/sec)	186	537	932
Feed rate (C)	(mm /rev)	0.103	0.0823	0.1455
Depth of cut (D)	(mm)	0.25	0.50	0.75

4. Results and discussion :

According to design of experiment a statistical analysis was done for the experimental data obtained which are shown in table 3 from the L_{27} experiments. By using minitab-17software, the average performance and S/N ratio were calculated for various responses. Analysis of variance (ANOVA) was performed to identify the most significant control parameter and to quantify their effects on the different responses.

Table 5. Central Composite Rotatable Design Different Controlling Parameters and Results

1	TOOL COATING	CUTTING SPEED (mm/s)	D – OF CUT (mm)	FEED RATE (mm/rev)	MRR (mm^3/s)	MEAN Ra µm	MEAN ROUNDNESS ERROR µm
1	PC (9030)	186	0.25	0.082	3.813	2.587	20.97
2	PC (9030)	186	0.25	0.082	3.813	2.588	19.90
3	PC (9030)	186	0.25	0.082	3.813	2.638	20.45
4	PC (9030)	537	0.50	0.100	26.850	1.803	18.92
5	PC (9030)	537	0.50	0.100	26.85	1.633	18.24
6	PC (9030)	537	0.50	0.100	26.850	1.644	16.44
7	PC (9030)	932	0.75	0.145	101.355	1.649	11.36
8	PC (9030)	93	0.75	0.145	101.355	1.690	16.25
9	PC (9030)	932	0.75	0.145	101.355	1.667	16.46
10	PC (5400)	186	0.50	0.145	13.485	2.697	19.78
11	PC (5400)	186	0.50	0.145	13.485	2.669	19.64
12	PC (5400)	186	0.50	0.145	13.485	2.679	20.11
13	PC (5400)	537	0.75	0.082	33.026	2.488	17.95
14	PC (5400)	537	0.75	0.082	33.026	2.381	18.89
15	PC (5400)	537	0.75	0.082	33.026	2.470	17.82
16	PC (5400)	932	0.25	0.100	23.300	1.574	12.28

17	PC (5400)	932	0.25	0.100	23.300	1.566	13.85
18	PC (5400)	932	0.25	0.100	23.300	1.494	15.00
19	NC (5330)	186	0.75	0.100	13.950	2.220	17.64
20	NC (5330)	186	0.75	0.100	13.950	2.117	16.14
21	NC (5330)	186	0.75	0.100	13.950	2.228	17.36
22	NC (5330)	537	0.25	0.145	19.466	1.717	18.92
23	NC (5330)	537	0.25	0.145	19.466	1.730	18.24
24	NC (5330)	537	0.25	0.145	19.466	1.725	16.44
25	NC (5330)	932	0.50	0.082	38.212	1.352	10.07
26	NC (5330)	932	0.50	0.082	38.212	1.411	10.62
27	NC (5330)	932	0.50	0.082	38.212	1.378	11.21

4.1. Effect of Process Parameters on Surface Roughness:

From fig (2), for minimum surface roughness the optimal parametric combination is $A_3B_3C_2\,D_2$. Table (4) showed that the cutting speed is the most significant factor on surface roughness followed by tool coating material, feed rate and depth of cut respectively. From ANOVA table (5) it is clear that cutting speed is the most significant factor on surface roughness with 71.28% contribution, followed by tool coating with 16.78% and finally by feed rate with 8.88%.

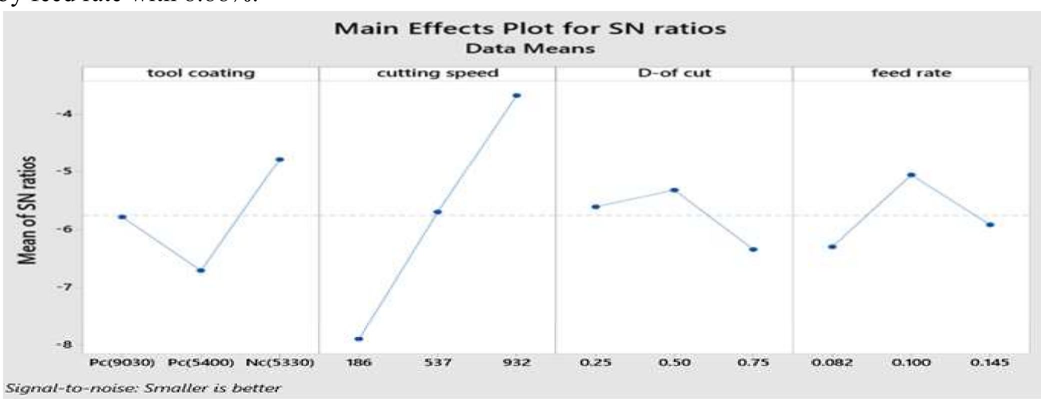


Fig.2 Main effects plot for SN ratios for Ra

Table 4. Response Table for Signal to Noise Ratios for Ra

Smaller is better

Level	Tool coating	Cutting speed	D-of cut	Feed rate
1	-5.782	-7.895	-5.608	-6.265
2	-6.706	-5.695	-5.317	-5.055
3	-4.778	-3.676	-6.342	-5.915
Delta	1.927	4.219	1.025	1.240
Rank	2	1	4	3

Table 5.ANOVA for Ra model

Source	**DF**	**Adj SS**	**Adj MS**	**F-Value**	**P-Value**	**Contribution %**
tool coating	2	0.95191	0.47595	208.97	0.000	16.28 %
Cutting speed	2	4.16749	2.08374	914.86	0.000	71.28 %
D-of cut	2	0.16686	0.08343	36.63	0.000	02.85 %
Feed rate	2	0.51888	0.25944	113.91	0.000	08.88 %
error	18	0.04100	0.00228	-	-	00.71 %
total	26	5.84614	-	-	-	100 %

4.2. Effect of the Parameters on Material Removal Rate:

From fig (3), for maximum material removal rate the optimal parametric combination is $A_3B_3C_3D_3$. Table (6) showed the signal to noise ratios for material removal rate , it is clear that cutting speed is the most significant factor on material removal rate followed by depth of cut and feed rate respectively. From ANOVA table (7), it is clear that cutting speed has the highest contribution percentage on metal removal rate with a contribution of 45.1% followed by depth of cut with 14.52% and finally tool coating with 12.765%.

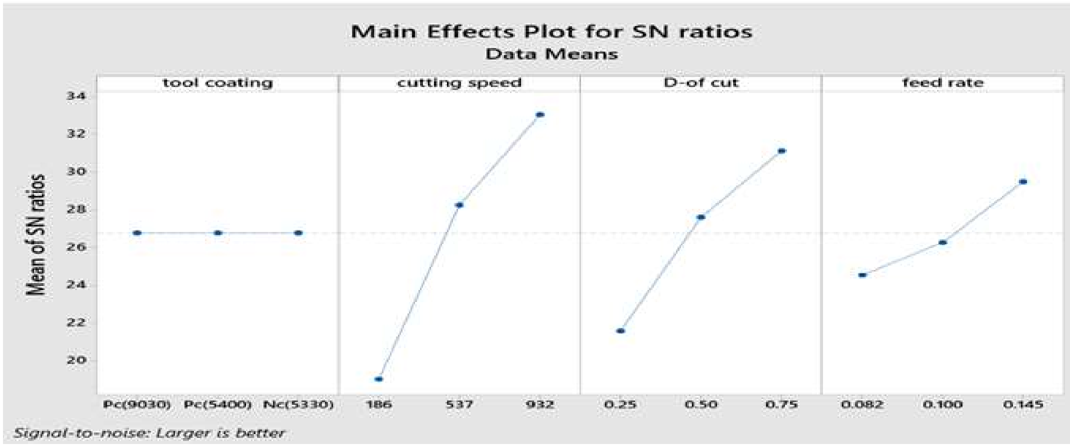


fig.3 Main effects plot for SN ratios for MRR

Table 6. Response Table for Signal to Noise Ratios for MRR
Larger is better

Level	Tool coating	Cutting speed	D-of cut	Feed rate
1	26.77	19.04	21.95	24.55
2	26.77	28.25	27.61	26.27
3	26.77	33.04	31.13	29.50
Delta	0.00	14.00	9.54	4.95
Rank	4	1	2	3

Table7. ANOVA for Material Removal Rate Model

Source	**DF**	**Adj SS**	**Adj MS**	**F-Value**	**P-Value**	**Contribution %**
tool coating	2	2506.7	1253.33	-	-	12.76 %
Cutting speed	2	8871.0	4435.51	-	-	45.16 %
D-of cut	2	2853.4	1426.68	-	-	14.52 %
Feed rate	2	5415.0	2707.50	-	-	27.56 %
error	18	0.0	0.00	-	-	00.00 %
total	26	19646.0	-	-	-	100 %

4.3. Effect of the Parameters on Roundness error:

From fig (4) for minimum roundness error the optimal parametric combination is $A_3B_3C_2\, D_1$ .Table (8) showed that the cutting speed is the most significant factor on roundness error followed by coating material of cutting tool insert, feed rate and depth of cut respectively. From ANOVA table (9), it is obvious that, the highest contribution percent on roundness error is the cutting speed cutting with a contribution of 71.1% followed by coating material of cutting tool insert with 11.97%.

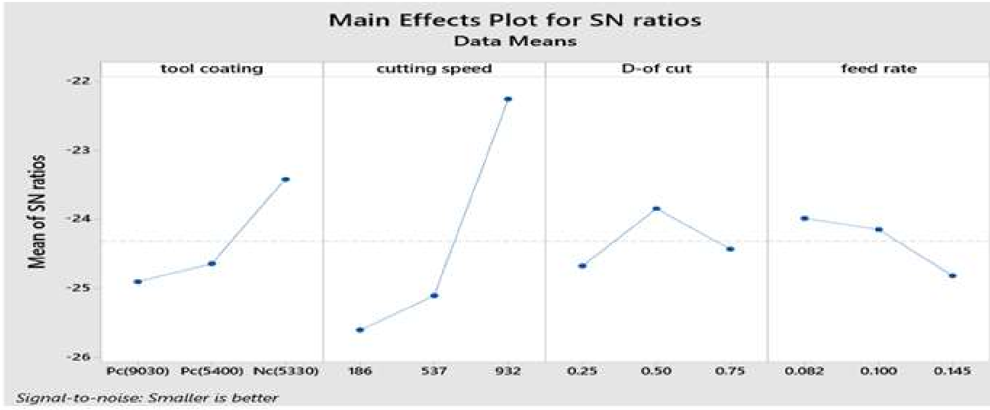


Fig .4. Main effects plot for SN ratios for roundness error

Table 8. Response Table for Signal to Noise Ratios for Roundness error
Smaller is better

Level	Tool coating	Cutting speed	D-of cut	Feed rate
1	- 24.91	- 25.60	- 24.68	- 23.99
2	- 24.64	- 25.11	- 23.85	- 24.15
3	- 23.41	- 22.25	- 24.43	- 24.82
Delta	1.49	3.35	0.83	0.83
Rank	2	1	4	3

Table 9. ANOVA for roundness error Model

Source	**DF**	**Adj SS**	**Adj MS**	**F-Value**	**P-Value**	**Contribution %**
tool coating	2	31.899	15.949	9.49	0.002	11.97 %
Cutting speed	2	189.541	94.770	56.37	0.000	71.10 %
D-of cut	2	6.759	3.380	2.01	0.163	02.54 %
Feed rate	2	8.127	4.064	2.42	0.118	03.04 %
error	18	30.262	1.681	-	-	11.35 %
total	26	266.588	-	-	-	100 %

5. CONCLUSION

On the basis of the experimental results during machining of stainless steel 304**,** following conclusions are drawn as listed below.

(1) The cutting speed has a most significant effect on surface roughness with 71.28 % contribution followed by coating material of cutting tool insert with16.28 %.

(2) The cutting speed has a most significant effect on material removal rate with 45.16 % contribution followed by depth of cut with14.52 and then tool coating with 12.76% %.

(3) The cutting speed has a most significant effect on roundness with 71.10 % contribution followed by coating material of cutting tool insert with11.97 %.

(4) For minimum surface roughness, the optimal parametric combination is $A_3B_3C_2$ D_2,for material removal rate is maximum at the parametric combination is $A_3B_3C_3D_3$ and finally for minimum roundness error, the optimal parametric combination is $A_3B_3C_2D_1$.

References

[1] Sahoo, Parametric analysis and optimization of turning operation by using Taguchi approach. International Journal of Modern Engineering Research, Vol. 3(4), pp 2154-2156, 2013.

[2] Chaudhari et al. Optimization of process parameters using Taguchi approach with minimum quantity lubrication for turning. International Journal of Engineering Research, Vol (4),pp 1268-1273, 2011.

[3] Sodhi and Singh, Parametric analysis of copper for cutting processes using turning. International Journal of Research in Mechanical Engineering &Technology, Vol. 3(2),pp 202-213, 2013.

[4] Dave et al. Effect of machining conditions on MRR and surface roughness during CNC Turning of different materials Using TiN coated cutting tools. International Journal of Industrial Engineering Computations, Vol. 3, pp 925-930, 2012.

[5] H. K. Dave, L. S. Patel and H. K. Raval, "Effect of Machining Conditions on MRR and Surface Roughness During CNC Turning of Different Materials using Tin Coated Cutting Tools – A Taguchi Approach", International Journal of Industrial Engineering Computations, vol. 3, pp. 925-930, 2012.

[6] IlhanAsilturk and Harun Akkus, "Determining the Effect of Cutting Parameters on Surface Roughness in Hard Turning using the Taguchi Method", Measurement, vol. 44, pp. 1697–1704, 2011.

[7] Jakhale Prashant P. and Jadhav B. R., "Optimization of Surface Roughness of Alloy Steel by Changing Operational Parameters and Insert Geometry in the Turning Process", International Journal of Advanced Engineering Research and Studies, II/ IV, pp. 17-21, 2013.

[8] M. Kaladhar, K. V. Subbaiah, Ch. Srinivasa Rao and K. Narayana Rao, "Application of Taguchi Approach and Utility Concept in Solving the Multi-Objective Problem when Turning AISI 202 Austenitic Stainless Steel", Journal of Engineering and Technology Review, vol. 4, pp. 55-61, 2011.

[9] Mishra and Gangele, Application of Taguchi method in optimization of tool flank wear width in turning operation of AISI 1045 Steel. Industrial Engineering Letters, Vol.1, pp .11-18, 2012.

[10] Feng C. X. and Wang X., "Development of Empirical Models for Surface Roughness Prediction in Finish Turning", International Journal of Advanced Manufacturing Technology, vol. 20, pp 348-356, 2002 .

[11] M. Kaladhar, K.Venkata Subbaiah and Ch. Srinivasa Rao, "Parametric Optimization During Machining of AISI 304 Austenitic Stainless Steel using CVD Coated DURATOMICTM Cutting Insert", International Journal of Industrial Engineering Computations, vol. 3, pp. 577–586, 2012.