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OPTIMIZATION OF CUTTING PARAMETERS FOR DRY TURNING OF EN9 STEEL WITH MTCVD MULTICOATED CARBIDE INSERT USING TAGUCHI METHOD

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Abstract- The present study illustrates the performance of MTCVD multicoated carbide insert in dry turning of EN9 steel. The effect of insert and cutting parameter on surface roughness and MRR is investigated. The experiments were conducted at three different spindle speed, feed and depth of cut. The cutting parameters are optimized using Taguchi method and the effect of cutting parameters and tool material on surface roughness was evaluated by the analysis of variance. The analysis indicated that the parameter that have the biggest effect on surface roughness and MRR is feed.

Keywords*:* Turning process, surface roughness, MRR(Material removal rate), Taguchi method, ANOVA.

I. INTRODUCTION

In modern industry the goal is to manufacture low cost, high quality products in short time. Automated and flexible manufacturing systems are employed for that purpose along with computerized numerical control (CNC) machines that are capable of achieving high accuracy and very low processing time. Turning is the most common method for cutting and especially for the finishing machined parts. In turning process parameters such as cutting tool geometry and materials, the depth of cut, feed rates, cutting speeds as well as the use of cutting fluids will impact the material removal rates and the machining qualities like the surface roughness, the roundness of circular and dimensional deviations of the product 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, The surface roughness of the machined parts is one of the most significant product quality characteristics. This characteristic refers to the deviation from the nominal surface of the third up to sixth order. The actual surface profile is the superposition of error of the form, waviness and roughness. The order of deviation is defined in international standards. The surface roughness greatly affects the functional performance of mechanical parts such as wear resistance, fatigue strength, ability of distributing and holding a lubricant, heat generation and transmission, corrosion resistance, etc. The perfect surface quality in turning would not be achieved even in the absence of irregularities and deficiencies of the cutting process, as well as environmental effects. There are various parameters used to evaluate the surface roughness. In the present research, the average surface roughness (Ra) was selected as a characteristic of surface finish in turning operations. It is the most used standard parameter of surface roughness. This paper demonstrates the application of the Taguchi method for identifying the optimal cutting parameters for surface roughness in dry turning of EN9 steel.

II. LITERATURE REVIEW

Indrajit Mukherjeet al. [1] presented a brief review on different optimization techniques used for optimization of metal cutting processes.

L B Abhang et al[2]They found that taguchi method provide simple, systematic and efficient methodology for optimization of the machining process it is found that lubricant temp. and feed rate that influence surface roughness

R. R. Deshmukh et al [3] They found that speed has maximum effect & feed has minimum effect on surface roughness. *The* experiment was designed and carried out on the basis of standard L9 Taguchi orthogonal array At high speeds, surface finish is least affected. At low speeds surface roughness increases with increasing feed but at higher speeds surface roughness is less dependent on feed.

Ilhan Asilturk , et al [4] investigated the effects of cutting parameters on AISI 4140 with coated carbide cutting tools in Dry turning by employing Taguchi techniques.The Results shows that the feed rate effect more compared to cutting speed and doc on surface roughness at a reliability level of 95%.

N. Satheesh Kumara et al[5] Worked on different five carbon alloy steels used for turning and found that the better surface finish is achieved by turning carbon alloy steels at low feed rate and high spindle speeds

B Kumaragurubaran, P Gopal [6] have presented an experimental work on EN-9 steel with different cutting parameters like cutting speed, feed and depth of cut which influenced by response parameters like surface roughness and metal removal rate in turning. For experiment L9 orthogonal array using Taguchi's design of experiments are used and optimized by S/N ratio and analyzed by Analysis of variance (ANOVA's).they have find the dominating parameter of metal removal rate is feed rate and cutting speed is a dominating parameter for surface roughness.

D Philip Selvaraj et al [7] conducted dry and wet turning operation on nitrogen alloyed duplex stainless steel with coated carbide cutting tool inserts .they used taguchi method to optimize the cutting parameters. The results shows that the feed rate effect more on the surface roughness and cutting force for dry turning.

Ashvin J et al. [8]developed a mathematical model using response surface method (RSM) to predict the surface roughness of AISI 410 steel in dry turning. The cutting parameters considered were tool nose radius cutting speed, feed rate and depth of cut. They found that the surface roughness was found to increase with the increase in the feed and it decreased with increase in the tool nose radius.

Mustafa Gunay et al. [9] investigated the use of the Taguchi method for minimizing the average surface roughness (Ra) in turning of hardened high-alloy white cast iron at two different hardness levels (50 HRC and 62 HRC) using ceramic and cubic boron nitride (CBN) cutting tools Their study focused on effects of cutting parameter and tool materials on surface roughness. The Statistical analysis of experimental data indicated that the cutting speed and feed rate was have the biggest effect on Ra

R. Suresh, S. Basavarajappa et al. [10] have worked on AISI 4340 steel for hard turning. They have establish a correlation between cutting parameters such as cutting speed, feed rate and depth of cut with machining force, power, specific cutting force, tool wear and surface roughness on work piece Performance of multilayer hard coatings (TiC/TiCN/Al2O3) on cemented carbide substrate using chemical vapor deposition (CVD) for machining of hardened AISI 4340 steel was evaluated. The analysis of the result revealed that higher values of feed rates are necessary to minimize the specific cutting force. The combination of low feed rate and high cutting speed is necessary for minimizing the surface roughness

Rajesh Khatri et al. [11] investigate the effect of the spindle speed, feed rate and depth of cut on material removal rate (MRR) in turning of AISI 1045 steel using uncoated carbide insert in dry condition. The cutting parameters were the spindle speed of 800, 800 and 1000 rpm, feed rate of 0.5, 1.0 and 1.5 mm/rev, and depth of cut of 0.15, 0.20 and 0.25 mm. L9 orthogonal array of Taguchi design was used for conducting experiments and Analysis of Variance was used for analysis of result to find the maximum MRR. The optimum value of MRR was obtained at high values of cutting parameter. The results obtained for MRR using the proposed simulation model were in a good agreement with the experiments. The most significant factor that effect MRR is feed rate.

III. MATERIAL AND METHOD

The turning experiments were carried out in wet cutting conditions using a Hitachi Seiki 4NEII-600 2 Axis CNC turning center equipped with a maximum spindle speed of 3500 rpm the work piece material used was EN9 steel. Its sizes were Ø25mm X 70mm. The chemical composition of EN9 steel is given in Table 1. The turning tests were performed at three different spindle speeds (1000, 1300, and 1600 rpm) and three feed rates (0.05, 0.1 and 0.15 mm/rev) and three depth of cut (0.5, 0.75 and 1mm). The cutting experiments were conducted using CNMG 120408-5 TN 2000 (TIN/TICN/AL2O3/TIN) MTCVD multicoated insert mounted on a Tool holder PCLNL 2525M 12 tool holder. The surface roughness was measured using a Mitutoyo SJ-301P portable device with in the sampling length of 2.5 cm. For calculating MRR, the weight of the work piece was measured by "GOLD SCALES" weight measuring machine .The weight of the work piece was measured before machining and after machining. Taguchi robust design methodology is used to obtain the optimum conditions for lower surface roughness in turning of EN9 steel under wet conditions .Statistical software Minitab 16 is used to obtain results for Analysis of Mean (ANOM) and Analysis Of Variance (ANOVA).

Table 1. Chemical composition of en-9

C	Si	Mn	P	S
0.54%	0.193%	0.72%	0.034%	0.029%

Table 2. Mechanical Properties Of En9

Tensile Strength	% of Elongation	Hardness
700 N/mm^2	30%	224 HBW

Table 3. Experimental design and optimization process parameters with their values at 3 levels

Process Parameters	**Level 1**	**Level 2**	**Level 3**
Spindle speed	1000	1300	1600
Feed	0.05	0.1	0.15
depth of cut	0.5	0.75	1

The experimental layout was developed based on Taguchi's Orthogonal Array Experimentation Technique. An L9 Orthogonal Array Experimental layout was selected to satisfy the minimum number of experiment conditions for the factors and levels presented in Table IV

Table 4. L9 orthogonal array

Exp. No.	**Process Parameter**		
	Spindle speed (rpm)	**Feed (mm/rev)**	**Depth of cut (mm)**
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

The optimization of the measured control factors were provided by signal-to-noise (S/N) ratios. The lowest values of surface roughness are very important for quality improvement of the product. For this reason, the ''lower-the-better'' equation was used for the calculation of the S/N ratio. Table VI shows the values of the S/N ratios for observations of the surface roughness. The higher value of MRR are very important for increasing production. For this reason, the ''larger-the-better'' equation was used for the calculation of the S/N ratio. Design of Experiment [DOE] using Taguchi's Analysis & ANOVA for Main effects plot has been done using Minitab 16 application software. Results of the same with their respective graphs & interpretations are mentioned below in the sequential order.

Surface roughness

Table 5. Experimental data of surface roughness

Exp.No.	**Process Parameter**			**Surface Roughness Ra(µm)**	**SN Ratio For Ra**
	Spindle speed (rpm)	**Feed (mm/rev)**	**D.O.C (mm)**		
1	1000	0.05	0.5	2.435	-7.72998
2	1000	0.1	0.75	1.981	-5.93769
3	1000	0.15	1	1.122	-0.99986
4	1300	0.05	0.75	1.681	-4.51135
5	1300	0.1	1	0.959	0.36363
6	1300	0.15	0.5	1.144	-1.16852
7	1600	0.05	1	1.736	-4.79099
8	1600	0.1	0.5	1.504	-3.54496
9	1600	0.15	0.75	1.118	-0.96884

Table 6. Response Table for Signal to Noise Ratios of Ra Smaller is better

Level	spindle speed	Feed	Doc
1	-4.889	-5.677	-4.148
2	-1.772	-3.040	-3.806
3	-3.102	-1.046	-1.809
Delta	3.117	4.632	2.339
Rank	2	1	3

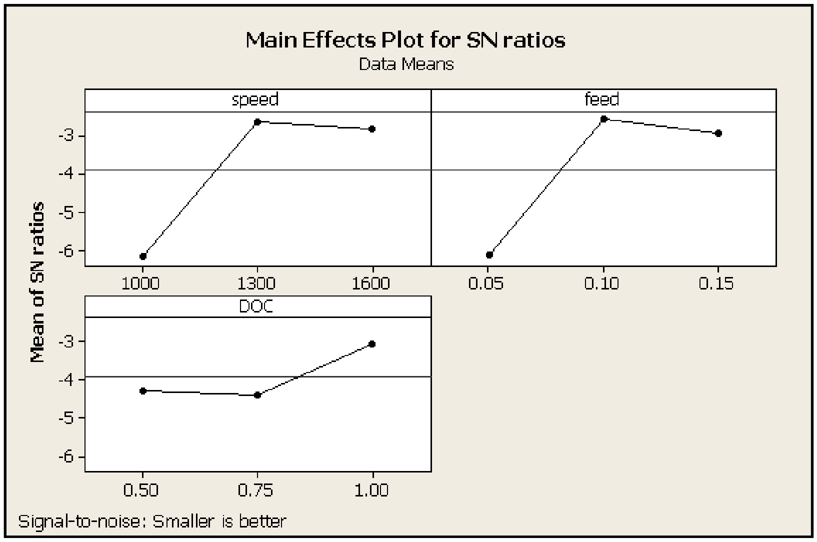

Fig.1. Main Effect plot for SN Ratios (surface roughness)

Table 7. Response Table for Signal to Noise Ratios of Ra Smaller is better

Level	spindle speed	feed	Doc
1	1.846	1.951	1.694
2	1.261	1.481	1.593
3	1.453	1.128	1.272
Delta	0.585	0.823	0.422
Rank	2	1	3

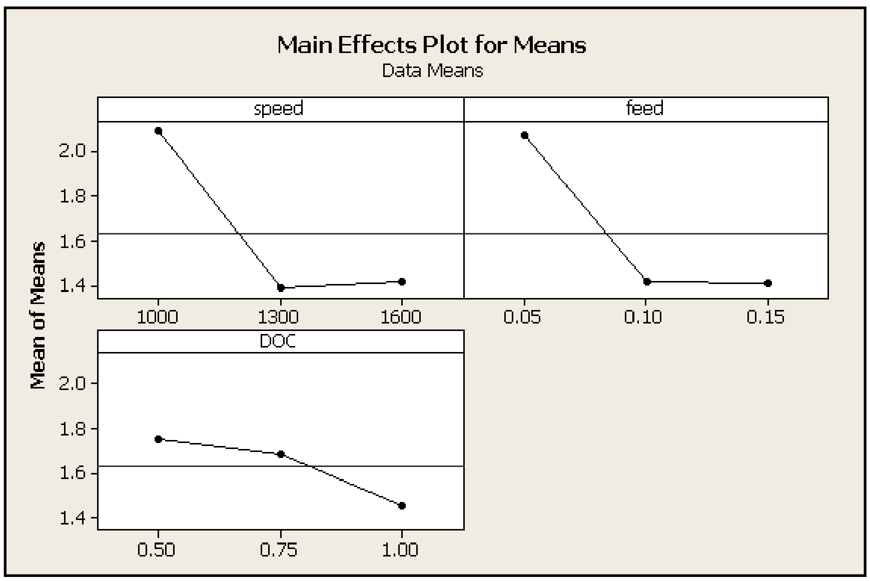

Fig.2. Main Effect plot for means (surface roughness)

Material Removal rate (MRR)

The MRR is expressed as the ratio of the difference of weight of the work piece before and after machining to the machining time and density of the material.

$$\frac{Wa - Wb}{\rho \times t}$$

Where,
Wa is the initial weight of work piece in g. Wb is the final weight of work piecein g. t is the machining time in second. ρ is the density of mild steel (7.85×10^{-3} g/mm^3).

Table 5. Experimental data of MRR.

Exp.No.	Process Parameter			MRR (mm^3/sec)	SN Ratio For Ra
	Spindle speed (rpm)	Feed (mm/rev)	D.O.C (mm)		
1	1000	0.05	0.5	54.447	34.7195
2	1000	0.1	0.75	170.381	44.6284
3	1000	0.15	1	380.407	51.6050
4	1300	0.05	0.75	109.495	40.7879
5	1300	0.1	1	338.275	50.5854
6	1300	0.15	0.5	216.421	46.7060
7	1600	0.05	1	204.011	46.1931
8	1600	0.1	0.5	182.919	45.2452
9	1600	0.15	0.75	393.034	51.8886

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

Level	spindle speed	feed	Doc
1	43.65	40.57	42.22
2	46.03	46.82	45.77
3	47.78	50.07	49.46
Delta	4.12	9.50	7.24
Rank	3	1	2

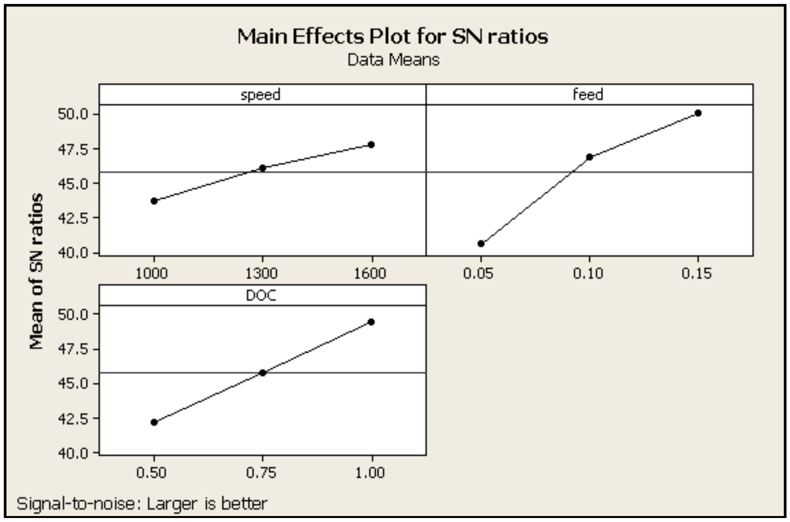

Fig.1. Main Effect plot for SN Ratios (MRR)

Table 7. Response Table for Signal to Noise Ratios of MRR larger is better

Level	spindle speed	feed	Doc
1	201.7	122.7	151.3
2	221.4	230.5	224.3
3	260.0	330.0	307.6
Delta	58.2	207.3	156.3
Rank	3	1	2

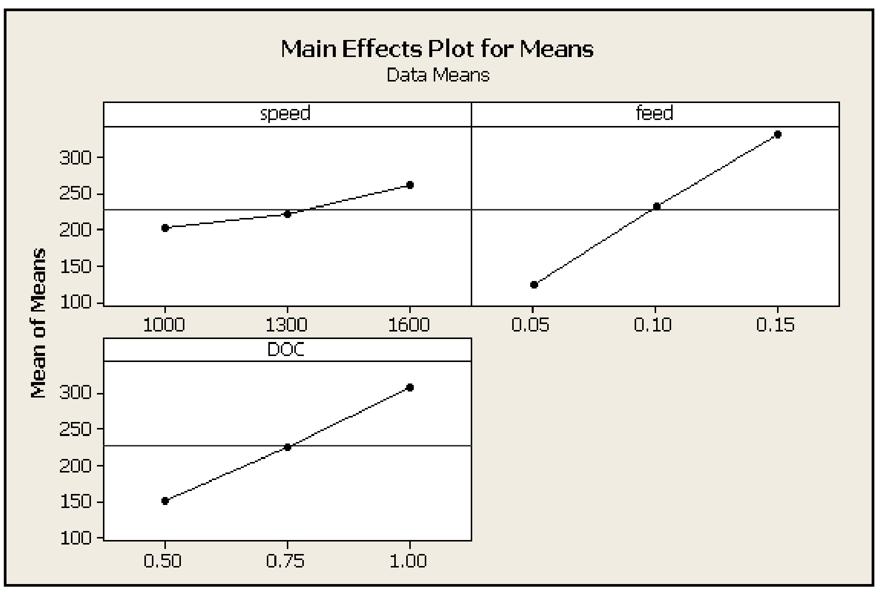

Fig.1. Main Effect plot for means (MRR)

IV. ANALYSIS OF VARIANCE (ANOVA)

Analysis of Variance was employed in order to analyze the experimental results. The analysis of variance is the statistical treatment most commonly applied to the results of the experiments to determine percentage contribution of each factor. The purpose of the ANOVA is to investigate which process parameters significantly affect the performance characteristics.

Table 8. Analysis of Variance for Ra, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P	% Contribution
Speed	2	0.53315	0.53315	0.26658	10.19	0.089	28.08
Feed	2	1.02190	1.02190	0.51095	19.54	0.049	53.82
Doc	2	0.29133	0.29133	0.14566	5.57	0.152	15.34
Error	2	0.05230	0.05230	0.02615			2.75
Total	8	1.89868					100
R-Sq = 94.34%				R-Sq(adj) = 77.36%			

Table 8. Analysis of Variance for Ra, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P	% Contribution
Speed	2	5268	5268	2634	0.82	0.131	0.04
Feed	2	64497	64497	32249	10.10	0.140	57.15
Doc	2	36698	36698	18349	5.75	0.497	32.51
Error	2	6387	6387	3193			5.65
Total	8	112850	112850				100
R-Sq = 93.24%				R-Sq(adj) = 72.97%			

V. RESULTS & DISCUSSIONS

The following conclusions can be drawn based on the results of the experimental study on turning EN9 steel with coated carbide tool

- The significant parameters can be easily identified and rank the parameter as per the response table for S/N Ratio and means.
- The rank order is clearly seen from the response table, feed is on 1 rank, spindle speed is on 2 rank and DOC is on 3 is on rank for surface roughness.
- The rank order is clearly seen from the response table, feed is on 1 rank, DOC is on 2 rank and spindle speed is on 3 rank for MRR.
- Analysis of Variance table shows the effect of parameter on surface roughness. From this table the significant parameters can be easily identified. Feed is a most significance factor for surface roughness and it has p-value<0.05
- The optimum condition for minimum surface roughness is Speed (1300rpm), Feed (0.1 mm/rev), and DOC (1 mm).
- The optimum condition for maximum MRR is Speed (1600rpm), Feed (0.15 mm/rev), and DOC (1 mm).
- The Analysis of Variance table can also justify the rank order of significant parameter as Feed (53.82), spindle Speed (28.08) and DOC. (15.34).It is clearly seen from the Analysis of variance that feed is the most significant parameter for surface roughness.
- The Analysis of Variance table can justify the rank order of significant parameter as Feed (57.15), DOC. (32.51) and spindle Speed (0.04).It is clearly seen from the Analysis of variance that feed is the most significant parameter for Material removal rate (MRR).

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WEB SITE LINKS

[1] Minitab's Stat Guide
http://www.minitab.co

