OPTIMIZATION OF PROCESS PARAMETERS FOR SURFACE ROUGHNESS OF AISI 4340 ALLOY STEEL USING A PVD COATED TOOL BY TAGUCHI METHOD

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Abstract: Metal cutting processes are industrial processes in which metal parts are shaped or removal of unwanted material. It is one of the most important and widely used manufacturing processes in engineering industries. Surface finish is one of the prime requirements of customers for machined parts. Good surface finish not only assures quality, but also reduces manufacturing cost, assembly time, avoids the need for secondary operation and leads to overall cost reduction. In the study of metal cutting, the output quality is rather important. A significant improvement in output quality may be obtained by optimizing the cutting parameters.

The main objective of the present work is to investigate the effects of different cutting parameters (Speed, feed and depth of cut) on surface roughness in turning of AISI 4340 alloy steel. PVD coated tool was used as wear resistive tool in order to achieve desire surface finish. Taguchi methodology has been applied to optimize cutting parameters using MINITAB 15 software, in order to planning the experimental runs. Lathe machine was used to conduct the experiment and the specimen was turned under different level of parameters in dry condition and measured the surface roughness using a surface tally meter. Analysis of Variance was used to investigate percentage contribution of each process parameters on output response.

In addition, a linear regression equation is modelled as a function of cutting parameters to predict values for surface roughness in comparison with experimental values within reasonable limit. Based on the main effects plots and signal-to-noise ratio (S/N) obtained through Taguchi approach, were used to relate the optimum level for surface roughness chosen from the considered three levels of cutting parameters.

I. INTRODUCTION

The critical objective in the current commercial ventures is to make the item with lower cost and with high caliber in limited capacity to focus time. There are two fundamental viable issues that specialists face in an assembling procedure, the first is to decide the estimations of procedure parameters that will yield the yearning item quality (meet specialized particulars) and the second is to augment producing framework execution utilizing the accessible assets.

The test of present day machining industry is essentially centered around accomplishment of high caliber, as far as work piece dimensional precision, surface completion, high creation rate, less wear on the cutting apparatuses ,economy of machining as far as cost sparing and build the execution of the item with decreased natural impact.

TURNING OPERATION

Turning is a type of machining or material expulsion process which is utilized to make rotational parts by removing undesirable material as appeared in fig 1.1 ,the turning process requires a turning machine or a machine ,work piece ,installation and cutting instrument .the work piece is a bit of re-molded material that is secured to the apparatus ,which itself is joined to the transforming machine the cutting device sustains into the pivoting work and removes material as Little chips to make the wanted shape.

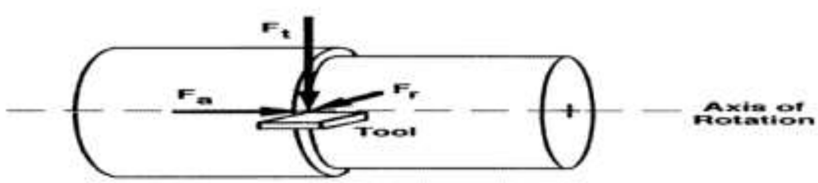


Fig : Turning process

OBJECTIVES OF THE PRESENT WORK

The objectives of present work are:

Conducting experimentation by application of orthogonal array for design of experiments and implementing Taguchi method for finding the effect of cutting parameters.

Study the effects of surface roughness on the AISI 4340 alloy steel by considering speed, feed and depth of cut in different combinations on turning operation.

II. EXPERIMENTAL PROCEDURE AND METHODOLOGY

An engine lathe was used for conducting the experiments. AISI 4340 alloy steel was used as the work material and PVD coated cemented carbide was used as the cutting tool. The average surface roughness on the work piece was measured using mitutoyo SJ-201P surface roughness measuring instrument. The experimentation of this work was based on Taguchi's design of experiments have to be carried out when the number of the process parameters increases. To solve this task, the Taguchi method uses a special design of orthogonal arrays to study the entire parameter space with a small number of experiments only. In this work, three cutting parameters namely, spindle speed, depth of cut and feed rate were considered for experimentation .Accordingly there are three input parameters and for each parameter three levels were assumed. For three factors, three level experiments, Taguchi had specified L27 (3^3) orthogonal array experimentation was recorded and further analyzed. Table1 shows the parameters and their levels considered for experiment. The tests were carried for a work piece bar of 50mm Diameter and 300mm length in a PSGA141 Lathe.

PVD **c**oated cemented carbide for the different alloying elements of AISI4340 alloy steels are shown in Table 2&3
The various Mechanical properties of En 24 steel are shown in Table 4.
The various properties of En 24 are shown in Table 5

The process parameters and their levels:

The cutting parameters of machining of EN24 steel are cutting speed, depth of cut and feed are taken as shown in table.

Cutting Parameters	Level 1	Level 2	Level 3
Cutting Speed(rpm)	450	580	740
Feed(mm/rev)	0.05	0.07	0.09
Depth of cut(mm)	0.10	0.20	0.25

Table 1: The process parameters and their levels

	C	Si	Mn	NI	Cr	Mo	S	P
% Of Composition	0.35 to 0.45	0.1 to 0.30	0.5 to 0.4	1.3 to 1.8	0.9 to 1.4	0.2 to 0.35	0.4	0.35

Table 2: Chemical composition of AISI 4340 alloy Steel

Typical Chemical Composition of PVD Coated Cemented carbide Tool, Cemented carbide as base metal coated with ($TiN+Al_2O_3+TiCN$)

Type of constituent	Acronym	Properties
TiN	Titanium nitride	It was the first PVD coating. It has all-round properties and a golden color.
Ti(C,N)	Titanium carbonitride	It is harder than TiN and adds flank wear resistance.
(Ti, Al) N	Titanium Aluminum nitride	It has high hardness in combination with oxidation resistance, which improves overall wear resistance.
Al_2O_3	Aluminum oxide	Is used for its chemical inertness and enhanced crater wear resistance.

Table3: PVD- coating constituents

Grade	En 24 (Range)
1. Max Stress	850-1000 N/mm²
2. Yield	650 N/mm²
3. Elongation	13%
4. Impact KCV	50Joules
5. Hardness	248-302 Brinell

Table 4: Mechanical Properties of AISI4340 alloy Steel

Physical Properties					
	Density (kg/dm3)	7.85			
	Modulus of elasticity 103 N/mm2	210			
	Thermal conductivity W/(m.K)	42			
	Electric resistivity Ohm.mm2/m	0.19			
	Specific heat capacity J/(kg.K)	460			
	Modulus of elasticity C 103 N/mm	100^0C	200^0C	300^0C	400^0C
		205	195	185	175
	Thermal expansion 106 m/(m.K)	100^0C	200^0C	300^0C	400^0C
		11.1	12.1	12.9	13.5

Table 5: Physical Properties of AISI4340 alloy Steel

The design of experiments (DOE) is an effective approach o optimize the throughout in various manufacturing –related processes. The DOE had been implemented to select minimum surface roughness of cylindrical work piece and cutting force is investigated the L27 orthogonal arrays was selected for this study.

EXPERIMENTAL DETAILS AND SPECIFICATION

Machine tool : PSGA141
Work material : AISI 4340 alloy steel
Cutting tool : PVD cemented carbide tool

Available cutting parameters and ranges
Speed V (rpm) : 360, 450, 580, 740,
Feed rate (mm/rev): 0.05, 0.07, 0.09,0.1,0.11
Depth of cut (mm) : 0.1, 0.2, 0.25, 0.5, 0.75
Cutting conditions : Dry cutting
Surface roughness measuring instrument: Mitotoyo SJ-201P+
Traverse speed: 1 mm/sec

TAGUCHI APPROACH

The target of the strong configuration is to locate the controllable procedure parameters setting for which Noise or variety as a negligible impact on the item or procedure useful qualities. It is to be noticed that the point is not to discover the parameter setting for the wild commotion variables yet the controllable outline variables. To achieve this target, the control parameter otherwise called inward cluster variables, are methodicallly changed as stipulated by the internal orthogonal exhibit. For the every trial of inward cluster, a progression of new examinations is directed by fluctuating the level settings of the wild clamor variables. The level mixes of commotion variables are done utilizing the external orthogonal exhibit. The obstruction of commotion on the execution qualities can be discovered utilizing the proportion where S is the standard induction of the execution parameters of the each internal exhibit examination and N is the aggregate number of trial in the external orthogonal cluster. This proportion shows the useful variety because of commotion. Utilizing this outcome, it is conceivable to foresee which control parameter settings will make the procedure in touchy to commotion. Taguchi strategy concentrates on vigorous outline through utilization of

1. Signal to noise ratio. 2. Orthogonal array.

TAGUCHI ANALYSIS OF THE S/N RATIO

SIGNAL TO NOISE RATIO

- Taguchi's emphasis on minimizing deviation from target led him to develop measures of process output that incorporate both the location of the output as well as the variation. These measures are called Signal to noise ratio.
- The Signal to Noise ratio provides the measure of the impact of noise factors and performance. The larger S/N, the more robust the product is against noise.
- Calculation of S/N ratio depends on experimental objective

1) AISI 4340 alloy steel and PVD coated cemented carbide tool

For the corresponding response surface roughness the signal to noise ratio and means are calculated by using the formula which is the lower the better value. The result obtained is tabulated as shown in the table above.

Ra versus speed (s), feed (f) and depth of cut (d)

Level	Speed	Feed	DOC(d)
1	10.559	9.114	9.956
2	10.728	10.063	10.742
3	10.507	12.617	11.097
Delta	0.221	3.503	1.141
Rank	3	1	2

Table 6: Response table for signal to noise ratio

1. The response data for surface roughness (Ra) versus speed(s), feed (f) and depth of cut (d), for three different levels are tabulated from the table 10.From the tables the response plots for mean effects, S/N ratios, and interaction data for mean are shown in graphs 2,3,4,5
2. For the PVD coated cemented carbide tool material the S/N ratios are plotted in the figures 4 and 5 and shows that level 2-3-3 for the parameters (speed, feed, depth of cut) is the best level of cutting conditions for the response- surface roughness(Ra).
3. The interaction parameters shown in the figure are between the speed*feed(s x f), speed*depth of cut(s x d), and feed*depth of cut (f x d) among these (s x f) and (s x d) has best interaction, because of it given biggest delta value from response table for S/N ratio. The following table shows the response table for means which depicts the influence of ratios cutting parameters.

LEVEL	SPEED	FEED	DOC(d)
1	3.454	2.871	3.230
2	3.476	3.219	3.498
3	3.437	4.277	3.639
DELTA	0.038	1.407	0.408
RANK	3	1	2

Table7: Response Table for Means

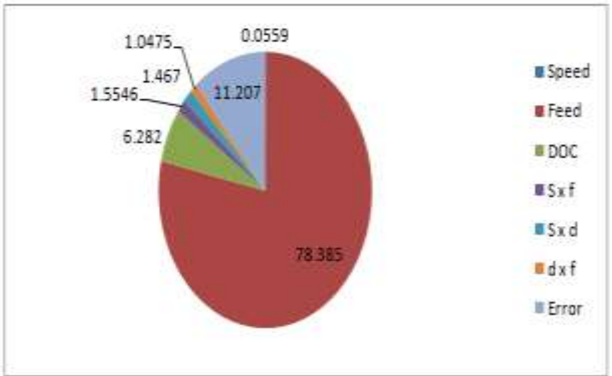
ANALYSIS OF VARIANCE

Analysis of variance is concerned with determining whether variances in two or more populations are significantly different. The experimental results were analyzed with the analysis of variance (ANOVA), which is used to investigate design parameters significantly affect the quality characteristic. This is too accomplished by separating the total variability of the S/N ratio, which is measured by the sum of squared deviations from total mean S/N ratio, into contributions by each of the design parameters and the error. The result of ANOVA on the surface roughness (Ra) is shown in the following Table

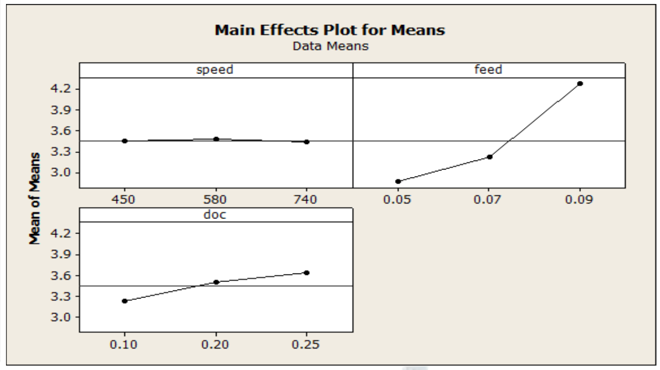
Ra versus speed (s) ,feed (f) and depth of cut (d) and interactions of parameters is also allowed to determine the effect of any two cutting parameters where as other parameter is maintained constant throughout the design of experiment.

Source	Degrees of freedom	sum of squares	Mean of squares	F-Ratio	% contribution
Speed	2	0.0069	0.00345	0.01999	0.0559
Feed	2	9.66015	4.83	27.977	78.385
DOC	2	0.77428	2.242	2.242	6.282
S x f	4	0.1916	0.2774	0.2774	1.5546
S x d	4	0.1808	0.0262	0.0262	1.467
d x f	4	0.1291	0.18652	0.18652	1.0475
Error	8	1.38117	0.17264	-	11.207
Total	26	12.324			100.000

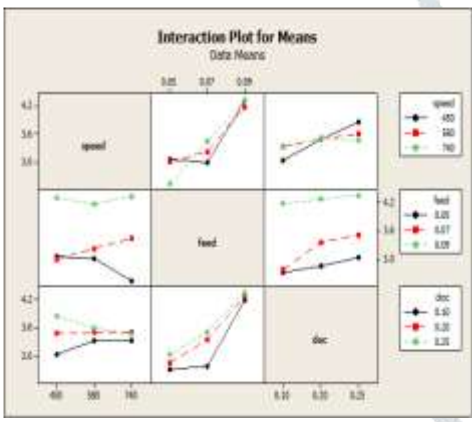
Table 8: Percentage contribution table



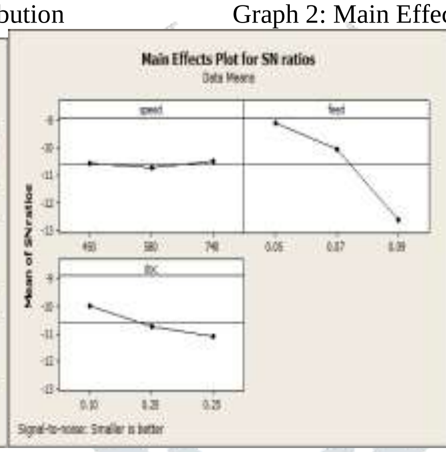
Graph 1: Pie chart for percentage contribution



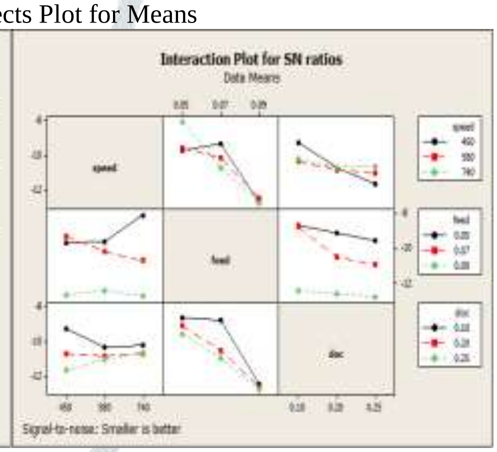
Graph 2: Main Effects Plot for Means



Graph 3: Interaction Plot for Means



Graph 4: Main Effects Plot for SN ratios



Graph 5: Interaction Plot for SN ratios

ANOVACALCULATIONS

Estimation of factor effects for response (Ra)

1. Correction factor (C.F) = $\frac{(\text{sum of total responses})^2}{\text{No.of responses}} = \frac{(\sum_{i=1}^{n} yi)^2}{n}$

   = 322.410

   Where n = No. of experiments = 27

   $Y_{i =}$ Response value in experiments.

2. Total sum of squares SS_{total} = $[\sum_{i=1}^{n} y^2]$ – CF

   SS_{total} = 334.734-322.410

   = 12.324

3. Sum of squares of response(Ra) for factor speed (S) :

$$SS_{speed} = \frac{(\text{sum of total in level 1})^2}{\text{No.ofobservations in level 1}} + \frac{(\text{sum of total in level 2})^2}{\text{No.ofobservations in level 2}} + \frac{(\text{sum of total in level 3})^2}{\text{No.ofobservations in level 3}} - \text{CF}$$

=0.0559

4. Sum of squares of response(Ra) for factor feed (SS_f)

$$(SS_f) = \frac{(\text{sum of total in level 1})^2}{\text{No.ofobservations in level 1}} + \frac{(\text{sum of total in level 2})^2}{\text{No.ofobservations in level 2}} + \frac{(\text{sum of total in level 3})^2}{\text{No.ofobservations in level 3}} - \text{CF}$$

= 9.66015

5. Sum of squares of response(Ra) for factor depth of cut (SSdoc)

$$(\text{SSdoc}) = \frac{(\text{sum of squares of level 1 })^2}{9} + \frac{(\text{sum of squares of level 2 })^2}{9} + \frac{(\text{sum of squares of level 3 })^2}{9} - \text{CF}$$

=0.77428

6. Sum of squares of response (Ra) for factor S x F , $SS_{s\ x\ f}$

$SS_{s\,x\,f} = \frac{(\text{sum of squares of level 1})^2}{9} + \frac{(\text{sum of squares of level 2})^2}{9} + \frac{(\text{sum of squares of level 3})^2}{9}$ - CF

=0.1916

7. Sum of squares of response (Ra) for factor S x d , $SS_{s\,x\,d}$

   $SS_{s\,x\,d} = \frac{(\text{sum of total in level 1})^2}{\text{No.ofobservations in level 1}} + \frac{(\text{sum of total in level 2})^2}{\text{No.ofobservations in level 2}} + \frac{(\text{sum of total in level 3})^2}{\text{No.ofobservations in level 3}}$ - CF

   = 0.1808

8. Sum of squares of response (Ra) for factor f x d, $SS_{fx\,d}$

$SS_{f\,x\,d} = \frac{(\text{sum of total in level 1})^2}{\text{No.ofobservations in level 1}} + \frac{(\text{sum of total in level 2})^2}{\text{No.ofobservations in level 2}} + \frac{(\text{sum of total in level 3})^2}{\text{No.ofobservations in level 3}}$ - CF

= 0.1291

9. Sum of squares for responses for residual factors

   $SS_{res} = SS_{total} – SS_{s} - SS_{f} – SS_{doc} – SS_{s\,x\,f} – SS_{s\,x\,d} – SS_{f\,x\,d}$

   = 12.324 - .0069- 9.66015- .77428 - .1916- .1808- .1291

   = 1.38117

10. Degrees of freedom

    DOF for factor (s), df_s = No.of levels – 1 =3-1 = 2

    DOF for factor (f), df_f= No.of levels – 1 =3-1 = 2

    DOF for factor (doc), df_d= 3-1 = 2

    DOF for Sx f,$df_{s\,x\,f}$ = 2 x 2 = 4

    DOF for Sx d,$df_{s\,x\,d}$ = 2 x 2 = 4

    DOF for fx d,$df_{f\,x\,d}$ = 2 x 2 = 4

    Total dof = df_{total} = No.of experiments – 1

    27-1 = 26

    DOF for residuals, $df_{res} = df_{total} – df_s – df_f - df_d$

    =26- 2- 2-2 = 20

11. Mean sum of squares

    For s , $Mss_s = \frac{SS\ s}{df\ s}$ = 0.00345

    For f, $Mss_f = \frac{SS\ f}{df\ f}$ = 4.830075

    For doc, $Mss_{doc} = \frac{SS\ doc}{df\ doc}$ = 0.38714

    For s x f , $Mss_{sf} = \frac{SS\ s\ x\ f}{df\ s\ x\ f}$ = 0.0479

    For s x d, $Mss_{s\,x\,d} = \frac{SS\ s\ x\ d}{df\ s\ x\ d}$ = .00452

    For f x d, $Mss_{f\,x\,d} = \frac{SS\ f\ x\ d}{df\ f\ x\ d}$ = 0.032275

    For residual, $Mss_{res} = \frac{SS\ res}{df\ res}$ = 0.17264

12. Sum of the squares due to error (SSE) = Sum of squares of residual errors

    = SS_{total} - sum

    = 12.324-10.9428

    = 1.38117

    Mean square error (MSSE) = $\frac{ss\ error}{8}$

13. F-Ratio

    $F_s = \frac{Mss\ s}{Mss\ res}$ = 0.01999

    $F_f = \frac{Mss\ f}{Mss\ res}$ = 27.977

    $F_{doc} = \frac{Mss\ f}{Mss\ res}$ = 2.242

    $F_{s\,x\,f} = \frac{Mss\ sf}{Mss\ res}$ = 0.2774

    $F_{s\,x\,d} = \frac{Mss\ s\ x\ d}{Mss\ res}$ = 0.0262

    $F_{f\,x\,d} = \frac{Mss\ f\ x\ d}{Mss\ res}$ = 0.18652

14. Percentage contribution

$$S = \frac{SSs}{\text{Total sum of squares}} = 0.063\%$$

$$F = \frac{SSf}{\text{ss total}} = 78.385\%$$

$$D = \frac{SSf}{\text{ss total}} = 6.282\%$$

$$S \times F = \frac{SSf}{\text{ss total}} = 1.5546\%$$

$$S \times d = \frac{SSf}{\text{ss total}} = 1.4670\%$$

$$F \times d = \frac{SSf}{\text{ss total}} = 1.0475\%$$

ANALYSIS OF REGRESSION FOR PREDICTION OF SURFACE ROUGHNESS (RA)

1. Regression equation is the best fit equation between the input factors output response. That is to say the relationship between surface roughness and machining independent variables (speed, feed and depth of cut) is stated by the following way.

$$Ra=K^* S^{a^*} F^{b^*} d^c$$

Where Ra = surface roughness in µm
S,F,d = Speed(rpm), Feed(mm/rev)and doc(mm)
a,b,c = constants

In order to facilitate the determination of constants and parameters the mathematical models of linearised by performing logarithmic transformation s are follows

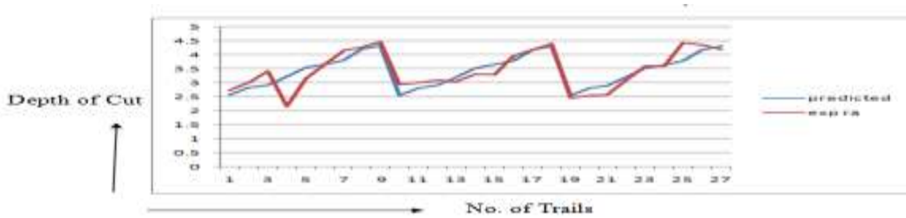
$$\text{Ln } Ra = \ln K + a^* \ln s + b^* \ln f + c^* \ln d$$

$$Ra = e^{3.33} * s^{-0.011} * f^{0.666} * d^{0.140}$$

2. Regression predicted surface roughness (Ra), are determined by performing regression analysis for the data shown in the table—using Minitab statistical tool. The regression equations obtained for the response (Ra) are shown below. Analysis is done for the following regression equations to get predicted surface roughness values. The following tables 1 shows the values for experimental surface roughness (Ra) and regression predicted surface roughness (Ra) for PVD tool on AISI 4340 material.
3. The plots for predicted Ra experimental Ra for PVD tool an AISI 4340 material are shown in fig—and it shows that the models are adequate without any violation of independency (or) constant assumption.

No. of Trails	Speed	Feed	DOC(d)	Ra	Predicted	SNRA1
1	450	0.05	0.1	2.751	2.57353	-8.78981
2	450	0.05	0.2	3.002	2.835786	-9.54821
3	450	0.05	0.25	3.432	2.925775	-10.7109
4	450	0.07	0.1	2.16	3.219961	-6.68908
5	450	0.07	0.2	3.158	3.548091	-9.98824
6	450	0.07	0.25	3.663	3.660684	-11.2767
7	450	0.09	0.1	4.166	3.806631	-12.3944
8	450	0.09	0.2	4.281	4.194546	-12.6309
9	450	0.09	0.25	4.47	4.327653	-13.0062
10	580	0.05	0.1	2.95	2.566356	-9.39644
11	580	0.05	0.2	3.02	2.827881	-9.60014
12	580	0.05	0.25	3.09	2.917619	-9.79917
13	580	0.07	0.1	3.058	3.210985	-9.70875
14	580	0.07	0.2	3.317	3.5382	-10.4149
15	580	0.07	0.25	3.303	3.650479	-10.3782
16	580	0.09	0.1	3.962	3.796019	-11.9583
17	580	0.09	0.2	4.185	4.182853	-12.4339
18	580	0.09	0.25	4.397	4.315589	-12.8631
19	740	0.05	0.1	2.47	2.559488	-7.85394
20	740	0.05	0.2	2.55	2.820313	-8.1308
21	740	0.05	0.25	2.57	2.90981	-8.19866
22	740	0.07	0.1	3.106	3.202391	-9.84403
23	740	0.07	0.2	3.598	3.528731	-11.1212
24	740	0.07	0.25	3.608	3.640709	-11.1453
25	740	0.09	0.1	4.45	3.78586	-12.9672
26	740	0.09	0.2	4.37	4.171659	-12.8096
27	740	0.09	0.25	4.214	4.304039	-12.4939

Table 9: Response table for predicted and experimental roughness



Graph 6: Experimental and predicted values of roughness

MATERIAL REMOVAL RATE (MRR)

Material removal rate (MRR) is the amount of material removed per time unit (usually per minute) when performing machining operations such as using a lathe or milling machine. MRR=V*F*D (in. Cu / Min)

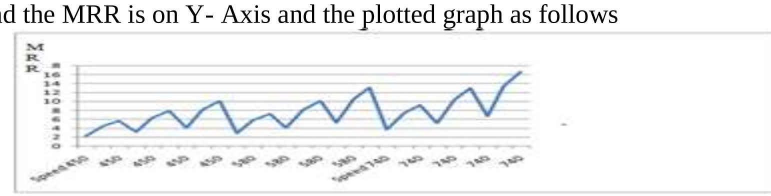
Where: V=Cutting Speed in RPM, F= Feed in mm/ revolution, D= Depth of cut in mm

No. of Trails	Speed	Feed	DOC(d)	MRR	No. of Trails	Speed	Feed	DOC(d)	MRR
1	450	0.05	0.1	2.25	15	580	0.07	0.25	10.15
2	450	0.05	0.2	4.5	16	580	0.09	0.1	5.22
3	450	0.05	0.25	5.625	17	580	0.09	0.2	10.44
4	450	0.07	0.1	3.15	18	580	0.09	0.25	13.05
5	450	0.07	0.2	6.3	19	740	0.05	0.1	3.7
6	450	0.07	0.25	7.875	20	740	0.05	0.2	7.4
7	450	0.09	0.1	4.05	21	740	0.05	0.25	9.25
8	450	0.09	0.2	8.1	22	740	0.07	0.1	5.18
9	450	0.09	0.25	10.125	23	740	0.07	0.2	10.36
10	580	0.05	0.1	2.9	24	740	0.07	0.25	12.95
11	580	0.05	0.2	5.8	25	740	0.09	0.1	6.66
12	580	0.05	0.25	7.25	26	740	0.09	0.2	13.32
13	580	0.07	0.1	4.06	27	740	0.09	0.25	16.65
14	580	0.07	0.2	8.12					

Table 10: Material Removal Rate (MRR)

GRAPHS BETWEEN MRR & SPEED

The speed is on the X-Axis and the MRR is on Y- Axis and the plotted graph as follows



Graph 7: MRR v/s Speed

SIGNAL FACTORS INFLUENCE ON RA FOR THE TOOL PVD ON AISI 4340 ALLOY STEEL

The plots consisting of mean effects for S/N Ratio and interaction plot for means, smaller-is-better (S/N Ratio) is selected as an objective of performance characteristics for minimizing the target Ra of signal factors speed, feed and depth of cut. Among the machining parameters **Feed** is the most influence parameter. For surface roughness (Ra).

Control factors	Speed(s)rpm	Feed (f) mm/rev	DOC(d) mm
Surface roughness (Ra) µm	580	0.09	0.25

Table 11: Optimized table obtained for AISI 4340 on PVD tool

IV. CONCLUSIONS AND FUTURE DIRECTION OF WORK

CONCLUSIONS

The analyzed results from turning AISI 4340 alloy steel with PVD (TiN+Al O_3+TiCN) coated cemented carbide inserts revealed the following conclusions.

- Taguchi is an efficient and systematical methodology for optimizing turning parameters and can be utilized rather than engineering judgment.
- It is observed that feed is the most influential controlling factor on surface roughness variation followed by depth of cut.
- Spindle speed was found to be insignificant on surface roughness.
- The optimal combination of process parameters for minimum surface roughness is obtained at 580 rpm, 0.09 mm/rev feed and 0.25 mm depth of cut.
- The ANOVA re related that the percentage contribution of feed (78.34%) is the dominant parameter followed by depth of cut (6.28%) for surface roughness.
- The average surface roughness values Ra resulted from machining En24 steel/ AISI 4340 alloy steel with PVD (TiN+Al2o3+TiCN) coated cemented carbide cutting tools is about 3.455 micro meters and having grade no 'N7'.
- The fluctuations of Ra values are explained by the fact that Ra depends on the turning parameters.

- The regression model was able to predict values for surface roughness with reasonable degree of approximation.
- ANOVA shows that interactions for the cutting parameters is found that speed and feed have greater influence on the response parameters Ra and the percentage contributions of speed and feed 1.05%.
- Using the experimental data, a multi linear regression model is developed and the values obtained for the response Ra is compared with experimental values. A graph is plotted between regression predicted values and an experimentally measured value which shows error between them is minimum.

FUTURE WORK

1. While the results declared through this experimental work may be generalized to a considerable extent while working on MMC (metal matrix composite), the study is limited to the extreme range of values of the cutting parameters specified. Further work may be directed towards applying the fine tune optimization of cutting parameters which was beyond the scope of the present work.

2. The work can be expended for multi objective optimization like surface roughness and tool life, and production cost, production time. The use of genetic algorithm which have the ability to adapt to the problem being solved under suggested by the evolutionary process of natural selection.

3.The effect of tool vibration, work piece hardness, cutting fluid, nose radius, tool material, acoustic emission can be considered has they have greater influence on surface roughness so, including all those along with speed, feed and depth of cut may be selected.

Following is a list of summarizing the future research opportunities in the area of machining of metal matrix composite.

- Efforts should be more to investigate effects of process parameters on various outputs responses in turning.
- Effect of different cooling environment on surface roughness and material removal rate in turning.
- Influence of process parameters on tool behavior in turning.
- Influence of matrix type reinforcement volume fraction and particle size in turning.
- Chip formation analysis in machining.

References

1. Optimizing surface roughness in turning operation using Taguchi method and ANOVA by HMSomasekhara, lakshamana swami ,January 2017 DOI: 10.17148/IARJSET/NCDMETE.2017.30
2. Optimizing cutting force for turned parts for Taguchi's parameters design approach by Hari Singh, pradeep Published 2005, Materials Science, Indian Journal of Engineering and Materials Sciences
3. Hasçalik, A., Çaydaş, U.: Optimization of turning parameters for surface roughness and tool life based on the Taguchi method. Int. J. Adv. Manuf. Technol. 38(9–10), 896–903 (2008)CrossRefGoogle Scholar
4. Akhavan Niaki, F., Mears, L.: A comprehensive study on the effects of tool wear on surface roughness, dimensional integrity and residual stress in turning IN718 hard-to-machine alloy. J. Manuf. Process. [Internet] 30, 268–280 (2017). https://doi.org/10.1016/j.jmapro.2017.09.016CrossRefGoogle Scholar
5. Zheng, G., Xu, R., Cheng, X., Zhao, G., Li, L., Zhao, J.: Effect of cutting parameters on wear behavior of coated tool and surface roughness in high-speed turning of 300M. Meas. J. Int. Meas. Confed. 2018(125), 99–108 (2017)Google Scholar
6. Asiltürk, I., Akkuş, H.: Determining the effect of cutting parameters on surface roughness in hard turning using the Taguchi method. Meas. 44(9), 1697–1704 (2011)Google Scholar