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Analysis of surface roughness during CNC Turning using Taguchi and Response Surface Methodology

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Abstract Surface roughness is of great importance for product quality and its function in manufacturing industries; also it is a common indicator of the quality characteristics for machining processes. The effect of surface roughness has been analyzed using Taguchi and Response Surface Methodology (RSM). L27 Orthogonal array has been employed for analysis. The results revealed that feed is the most significant factor in minimizing the surface roughness followed by depth of cut and then speed. Response surface methodology is a better tool for optimization and can better predict the effect of parameters on response.

Keywords - *Taguchi, Response Surface Methodology, Surface roughness, Orthogonal Array, CNC turning.*

I. INTRODUCTION

Quality plays a major role in today's manufacturing market. From Customer's viewpoint quality is very important because the quality of product affects the degree of satisfaction of the consumer during usage of the product. It also improves the goodwill of the company [15] .The surface roughness is of great importance for product quality and its function in manufacturing industries[2].Surface roughness is a common indicator of the quality characteristics for machining processes[5].The drastic increase of consumer needs for quality metal cutting related products (more precise tolerance and better surface finish) has driven the metal cutting industry to continuously improve quality control of the metal cutting processes[8] .

In actual machining, there are many factors which affect the surface roughness i.e. cutting conditions, tool variables and work piece variables. Cutting conditions include speed, feed and depth of cut and also tool variables include tool material, nose radius, rake angle, cutting edge geometry, tool vibration, tool overhang, tool point angle etc. and work piece variable include hardness of material and mechanical properties [15].

Upinder Kumar Yadav et al. [15] experimented and optimized machining parameters for surface roughness in CNC turning by Taguchi method. It was concluded that the surface roughness was mainly affected by feed rate and cutting speed. With the increase in feed rate the surface roughness also increased & as the cutting speed was decreased the surface roughness increased. From ANOVA analysis, parameters making significant effect on surface roughness were feed rate and cutting speed. Ilhan Asiltürk et al. [2] presented a method to determine optimal cutting conditions and mathematical models for surface roughness (response). Taguchi method was employed to determine the optimal turning process parameters. Second order model for surface roughness was obtained using RSM and the suitability of model was proved by ANOVA. Taguchi and RSM both indicated that the main effect of the feed rate is the most significant factor on the work piece surface roughness. Murat Sarikaya et al. [5] analysed CNC turning parameters under MQL using Taguchi design and response surface methodology. Analysis of Variance (ANOVA) demonstrated that the feed rate and the cooling conditions had the highest influence on machined surface roughness. Mathematical models were developed using response surface methodology to formulate the input cooling condition, cutting speed, feed rate and depth of cut to the R_a and R_z. The values of experimental and predicted were found to be very close to each other implying significance of models proposed for arithmetic average roughness (R_a) and average maximum height of the profile (R_z). Prajwalkumar M. Patil et al. [7] observed the effect of cutting parameters on the surface roughness and hardness. The author employed Taguchi method in the optimization of cutting parameters. The Analysis of means (ANOM) and Analysis of variance (ANOVA) were carried out to determine the optimal parameters level and obtain level of importance of each parameter. From the ANOVA it was observed that feed had maximum significance in case of R_a and R_z. Ranganath M S et al. [10] developed a prediction model of surface roughness for turning EN-8 steel with uncoated carbide inserts using Response Surface Methodology. The model was developed in the form of multiple regression equations correlating dependent parameter surface roughness with cutting speed, feed rate and depth of cut, in a turning process. Analysis of variance (ANOVA) was done to test for significance of regression model and on model coefficients, and test for lack of fit i.e. to check model adequacy. Cutting speed was found out to have the strongest effect on the surface roughness among the selected parameters; it was inversely proportional to the response. Surface Roughness was inversely proportional to depth of cut.

For the analysis the experimental data has been retrieved from Ranganath M Singari, "Optimization of process Parameters in turning operation of Aluminum (6061) with Cemented Carbide Inserts Using Taguchi and

ANOVA" [11]. The objective of this paper is to optimize the cutting parameters for obtaining minimum surface roughness. Taguchi techniques and Response Surface Methodology have been employed for the analysis. Further Comparison has been performed based on the results obtained from two techniques.

II. TAGUCHI METHOD

Taguchi's parameter design is an important tool for robust design. It offers a simple and systematic approach to optimize design for performance, quality and cost [9]. According to Dr.Genichi Taguchi, a robust design is one that is created with a system of design tools to reduce variability in product or process, while simultaneously guiding the performance towards an optimal setting. A product that is robustly designed will provide customer satisfaction even when subjected to extreme conditions on the manufacturing floor or in the service environment. Taguchi method is one of the important tools used for robust design to produce high quality products quickly and at low cost. Two major tools used in robust design are signal to noise ratio, which measures quality with emphasis on variation, and orthogonal array, which accommodates many design factors simultaneously [16]. Taguchi's design is a fractional factorial matrix that ensures a balanced comparison of levels of any factor. In this design analysis of each factor is evaluated independent of all other factors. By applying Taguchi's technique one can significantly reduce the time required for experimental investigation, as it is effective in investigating the effects of multiple factors on performance as well as to study the influence of individual factors to determine which factor has more influence and which has less[4].

Taguchi method is a powerful tool for the design of high quality systems. Taguchi method is efficient method for designing process that operates consistently and optimally over a variety of conditions. To determine the best design it requires the use of a strategically designed experiment. Taguchi approach to design of experiments in easy to adopt and apply for users with limited knowledge of statistics, hence gained wide popularity in the engineering and scientific community. The desired cutting parameters are determined based on experience or by hand book where cutting parameters are reflected [9].

Steps of Taguchi method are as follows:

1. Identification of main function, side effects and failure mode.
2. Identification of noise factor, testing condition and quality characteristics.
3. Identification of the main function to be optimized.
4. Identification the control factor and their levels.
5. Selection of orthogonal array and matrix experiment.
6. Conducting the matrix experiment.
7. Analyzing the data, prediction of the optimum level and performance.
8. Performing the verification experiment and planning the future action.

III. RESPONSE SURFACE METHODOLOGY

RSM is a collection of mathematical and statistical techniques that are useful for modeling and analysis of problems in which a response of interest is influenced by several variables and the objective is to optimize this response [12, 9]. RSM also quantifies relationships among one or more measured responses and the vital input factors. The work which initially generated interest in the package of technique was by Box and Wilson in 1951.

RSM can be used in the following ways:

1. To determine the factor levels that will simultaneously satisfy a set of desired specifications.
2. To determine the optimum combination of factors that yields a desired response and describes the response near the optimum.
3. To determine how a specific response is affected by changes in the level of the factors over the Specified levels of interest.
4. To achieve a quantitative understanding of the system behavior over the region tested.
5. To predict product properties throughout the region, even for a factor combinations not actually run.
6. To find the conditions necessary for process stability (insensitive spot).

In RSM, polynomial equations, which explain the relations between input variables and response variables, are constructed from experiments or simulations and the equations are used to find optimal conditions of input variables in order to improve response variables. For the design of RSM, central composite design (CCD) is used in this experiment. CCD is widely used for fitting a second order response surface. CCD consists of cube point runs, plus center point runs, and plus axial point runs. The three factors speed, feed rate, depth of cut, which were selected in the screening experiment, were used in CCD [9].

IV. EXPERIMENTATION AND ANALYSIS

Table 1 shows the cutting parameters considered and there levels. Table 2 shows the Standard L27 orthogonal array designed by Taguchi with the experimental results. The First Four columns of the Table 2 include the coding values of control factors. The last two columns of Table 2 include the measured value of surface roughness and corresponding Signal to Noise ratio values. The different units here are: speed-rpm, feed-mm/rev, depth of cut-mm and Surface Roughness Ra-μm. MINITAB 17 software has been used for the Analysis.

Table.1 Cutting Parameters and Levels

CODE	**Cutting parameter**	**Level 1**	**Level 2**	**Level 3**
A	Speed (rpm)	1700	1900	2100
B	Feed (mm/rev)	0.1	0.125	0.150
C	Depth of cut (mm)	0.2	0.3	0.4

Table.2. Design Table and Roughness readings [11]

EXPERIMENT NO	**A**	**B**	**C**	**Speeds (rpm)**	**Feed (mm/rev)**	**Depth of cut (mm)**	**Surface roughness (μm)**	**S/N Ratio**
1	1	1	1	1700	0.100	0.2	0.82	1.72372
2	1	1	2	1700	0.100	0.3	0.94	0.53744
3	1	1	3	1700	0.100	0.4	0.96	0.35458
4	1	2	1	1700	0.125	0.2	1.12	-0.98436
5	1	2	2	1700	0.125	0.3	1.06	-0.50612
6	1	2	3	1700	0.125	0.4	1.10	-0.82785
7	1	3	1	1700	0.150	0.2	1.44	-3.16725
8	1	3	2	1700	0.150	0.3	1.54	-3.75041
9	1	3	3	1700	0.150	0.4	1.50	-3.52183
10	2	1	1	1900	0.100	0.2	0.86	1.31003
11	2	1	2	1900	0.100	0.3	0.92	0.72424
12	2	1	3	1900	0.100	0.4	0.76	2.38373
13	2	2	1	1900	0.125	0.2	1.04	-0.34067
14	2	2	2	1900	0.125	0.3	1.20	-1.58362
15	2	2	3	1900	0.125	0.4	1.10	-0.82785
16	2	3	1	1900	0.150	0.2	1.44	-3.16725
17	2	3	2	1900	0.150	0.3	1.60	-4.08240
18	2	3	3	1900	0.150	0.4	1.50	-3.52183
19	3	1	1	2100	0.100	0.2	0.88	1.11035
20	3	1	2	2100	0.100	0.3	0.78	2.15811
21	3	1	3	2100	0.100	0.4	1.16	-1.28916
22	3	2	1	2100	0.125	0.2	1.08	-0.66848
23	3	2	2	2100	0.125	0.3	1.14	-1.13810
24	3	2	3	2100	0.125	0.4	1.26	-2.00741
25	3	3	1	2100	0.150	0.2	0.58	4.73144
26	3	3	2	2100	0.150	0.3	1.42	-3.04577
27	3	3	3	2100	0.150	0.4	1.86	-5.39026

4.1. Taguchi Technique

The aim of the present work is to minimize the surface roughness. Hence, “smaller the better type” classification for surface roughness has been selected. The S/N ratios for each of the 27 trials were calculated using the equation (1) and listed in Table.2.

$$\frac{S}{N} = -\log\left(\frac{(\sum y^2)}{n}\right) \quad - (1)$$

The main effect plot for means is shown in fig.1. They show the variation of individual response with three parameters i.e. speed, feed and depth of cut. In the plot x-axis represents the value of each process parameter and y-axis is response value. Horizontal line indicates the mean of the response. The main effect plots are used to determine the optimal design conditions to obtain the Minimum surface finish. It is evident from Fig.1 that Ra is Minimum at the Third level of speed (A), First level of Feed (B) and First level of Depth of cut (C).

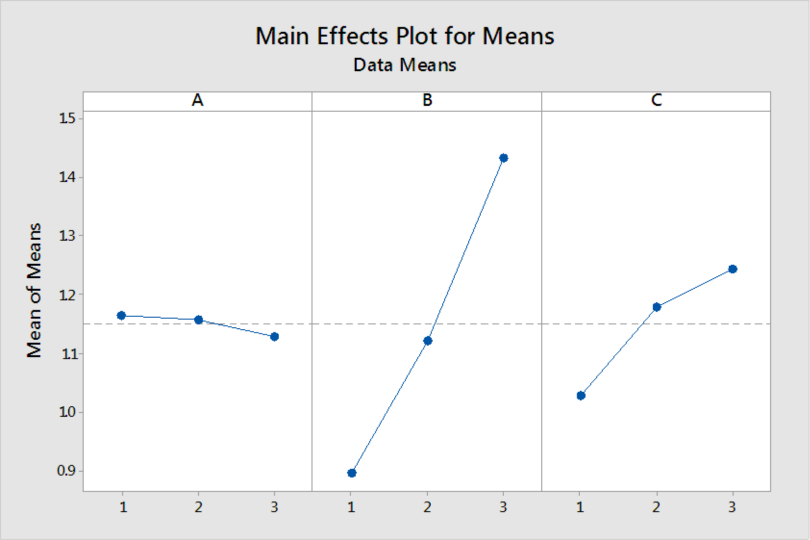

Figure.1. Main Effects Plot for Means

Fig. 2 represents main effects plot for Signal to Noise Ratio. The objective of using the Signal to Noise ratio as a performance measurement is to develop products and the processes insensitive to variance factor [1]. The signal to noise ratio indicates the degree of the predictable performance parameter of a product or process in the presence of noise factors. Process parameters setting with the highest Signal to noise ratio always yield the optimum quality with minimum variance. Consequently, the level that has a larger value finds the optimum level of each factor. In Fig.2 level three for speed (2100 rev/mm) has maximum S/N ratio value, which defines that the machining performance at such level gives minimum variation of the surface roughness. Hence, as indicated by main effect plots for S/N ratio, the ideal conditions for least surface roughness (Ra) are speed at level 3 (2100 rev/min), feed at level 1 (0.1 mm/rev) and depth of cut at level 1 (0.2 mm).

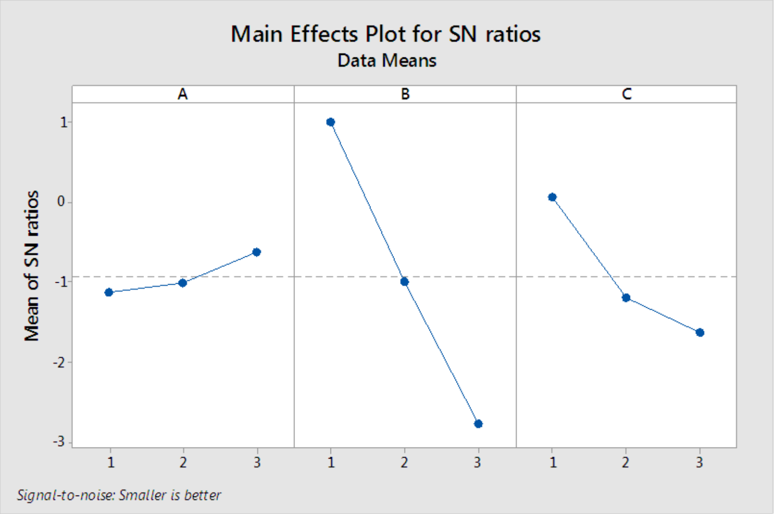

Figure.2. Main Effects Plot for SN ratios

The purpose of the analysis of variance (ANOVA) is to investigate which design parameter significantly affects the surface roughness [15].A better feel for the relative effect of the different factors can be obtained by the decomposition of the variance, which is commonly known as analysis of variance (ANOVA) [1]. Table 3 and Table 4 show the analysis of variance (ANOVA) for Means and S/N ratio respectively. In the present investigation, ANOVA and the F-test are applied to analyze the experimental data. ANOVA table shows that the percentage contribution of feed is Maximum. The most significant factor is Feed and after that depth of cut. The spindle speed has very less effect on the response in this experiment.

Table.3. ANOVA table for means

Source	DOF	Adj SS	Adj MS	F- Value	P-Value
A	2	.00643	.003215	.07	.930
B	2	1.29070	.645348	14.55	.000
C	2	.21923	.109615	2.47	.110
Error	20	.88714	.044357		
Total	26	2.40350			

S	R-sq	R-sq(adj)	R-sq(pred)
0.210611	63.09%	52.02%	32.73%

Table.4. ANOVA Table for Signal to Noise Ratio

SOURCE	DOF	Adj SS	Adj MS	F-Value	P-Value
A	2	1.296	0.6478	0.20	0.819
B	2	64.017	32.0086	9.96	0.001
C	2	13.807	6.9037	2.15	0.143
Error	20	64.296	3.2148		
Total	26	143.416			

S	R-sq	R-sq(adj)	R-sq(pred)
1.79299	55.17%	41.72%	18.29%

Table 5 and Table 6 are the response tables for Signal to Noise ratio and Mean. The response tables explain that the feed is the most dominant factor followed by depth of cut and speed.

Table.5. Response Table for S/N Ratios

Level	A (speed)	B (Feed)	C (Depth of cut)
1	-1.12690	1.00145	0.06084
2	-1.01174	-0.98716	-1.18740
3	-0.61547	-2.76839	-1.62754
Delta	0.51142	3.76984	1.68838
Rank	3	1	2

Table.6. Response Table for Means

Level	A (speed)	B (Feed)	C (Depth of cut)
1	1.1644	0.8978	1.0289
2	1.1578	1.1222	1.1778
3	1.1289	1.4311	1.2444
Delta	0.0356	0.5333	0.2156
Rank	3	1	2

The diagnostic checking has been performed through residual analysis for the developed model. The Residual plots for surface roughness are shown in Fig.3. These fall on a straight line implying that errors are distributed normally. From fig. 3 it can be further concluded that all the values are within the control range, indicating that there is no obvious pattern and unusual structure and also the residual analysis does not indicate any model inadequacy.

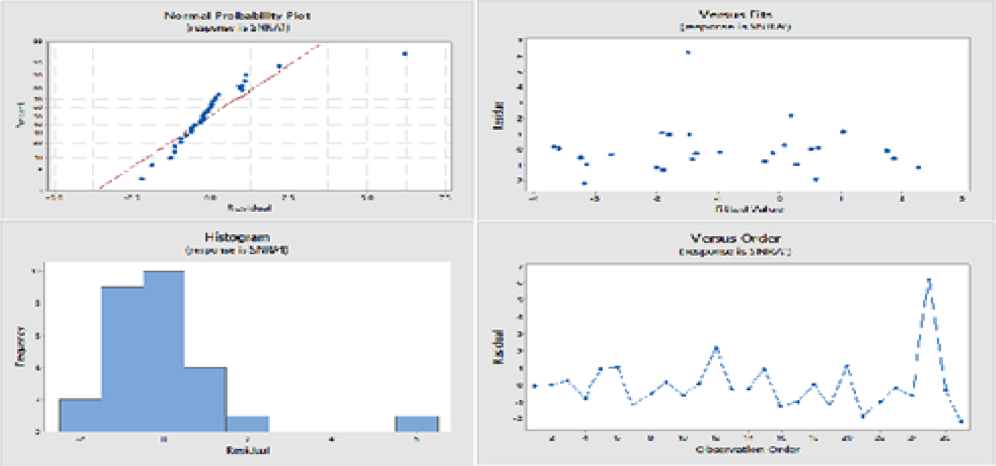

Figure.3. Residual Plots for SN ratios

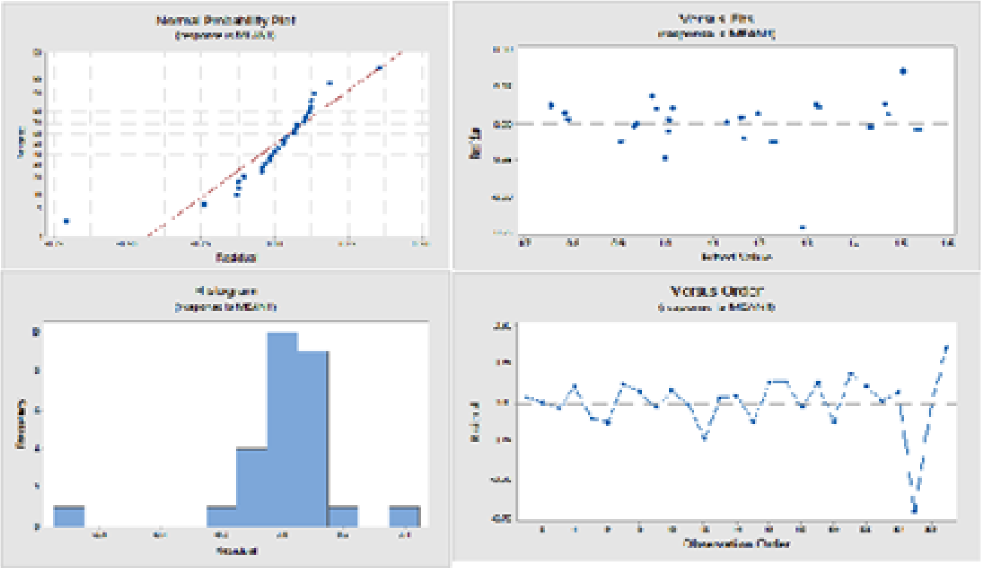

Figure.4. Residual plots for mean

4.2. RSM technique

The results from the machining trials performed as per the experimental plan are shown in Table 9. These results were input into the Minitab 17 Software for further analysis. Without performing any transformation on the response, examination of the fit summary output revealed that the quadratic model is statistically significant for all the conditions and, therefore, it has been used for further analysis. An ANOVA table is commonly used to summarize the tests performed. Table 10 shows the Analysis of Variance (ANOVA). The Model F value of 5.71 implies the model is significant. There is only 0.6% chance that an F-value this large could occur due to noise. Significance of Model is desirable as it indicates that the terms in the model have a significant effect on the response. Values greater than 0.1000 indicate the model terms are not significant. Some of the model terms were found to be significant. From ANOVA table B, C, AC and BC were found to be significant. From the ANOVA table feed was found to be the most significant Factor followed by depth of cut. P value of 0.756 for speed (Factor A) proves that speed is not a significant parameter for roughness. Fig. 5 showing residuals VS order for Ra revealed that they have no obvious pattern and unusual structure. This implies that the models proposed are adequate and there is no reason to suspect any violation of the independence or constant variation assumption. During Optimal Design of A, B, C the Response surface design selected is according to D-optimality. Number of candidate design points are 20.

Table.7. Central Composite Design

Factors	3	Replicates	1
Base runs	20	Total runs	20
Base blocks	1	Total blocks	1

Table.8. Two-level factorial: Full factorial

Cube points	8
Centre points in cube	6
Axial points	6
Center points in axial	0
ἀ	1

Table.9. Design Table (randomized)

RUN	BLK	A	B	C
1	1	-1	-1	-1
2	1	-1	0	0
3	1	0	0	0
4	1	1	1	1
5	1	1	-1	-1
6	1	1	1	-1
7	1	0	0	0

8	1	-1	1	1
9	1	-1	-1	1
10	1	0	0	0
11	1	0	0	0
12	1	1	-1	1
13	1	0	-1	0
14	1	0	0	0
15	1	1	0	0
16	1	-1	1	-1
17	1	0	0	1
18	1	0	1	0
19	1	0	0	0
20	1	0	0	-1

Table.10. Analysis of Variance (ANOVA)

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	9	1.29210	0.143566	5.71	0.006
Linear	3	0.83556	0.278520	11.08	0.002
A	1	0.00256	0.002560	0.10	0.756
B	1	0.50176	0.501760	19.96	0.001
C	1	0.33124	0.331240	13.18	0.005
Square	3	0.04734	0.015779	0.63	0.613
A*A	1	0.00874	0.008736	.35	0.569
B*B	1	0.02954	0.029536	1.18	.304
C*C	1	0.02051	0.020511	.82	.388
2- way interaction	3	0.40920	0.136400	5.43	0.018
A*B	1	0.07220	0.072200	2.87	0.121
A*C	1	0.23120	0.231200	9.20	0.013
B*C	1	0.10580	0.105800	4.21	0.067
Error	10	0.25132	0.025132		
Lack-of-fit	5	0.25132	0.050265		
Pure Error	5	0.00000	0.00000		
Total	19	1.54342			

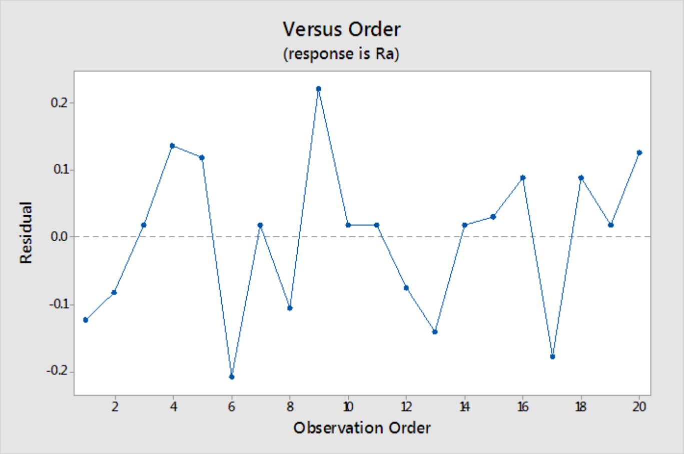

Figure.5. Residuals VS Order for RESPONSE

The 3D surface graphs for surface roughness are shown in Fig. 6, 7 and 8. All of them have curvilinear profile in accordance to the quadratic model fitted. Fig. 6 shows the interaction and direct effect of feed and speed on surface roughness. From Fig.6 it can be seen that at lower cutting speed (i.e. 1700rpm) with increase in feed (0.1 to .15mm/rev), has a significant increase on surface roughness whereas at higher cutting speed (i.e.2100rpm) with increase in feed (0.1 to .15mm/rev), has no significant increase on surface roughness.

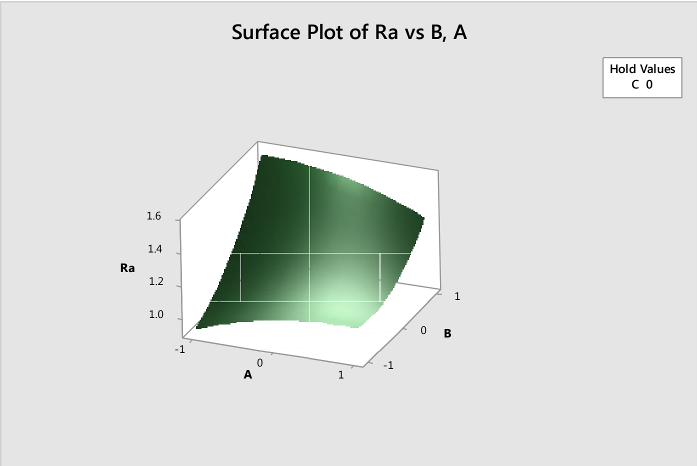

Figure.6. Surface Plot of Ra VS B, A

Fig. 7 shows the interaction and direct effect of Depth of cut and speeds on surface roughness. The above interaction figure evidenced that the feed rate and depth of cut on the surface roughness of turning surface has a significant effect. From Fig.7 it can be seen that at higher speed (i.e. 2100rpm) with increase in depth of cut (0.2 to 0.5mm) has a significant increase in surface roughness.

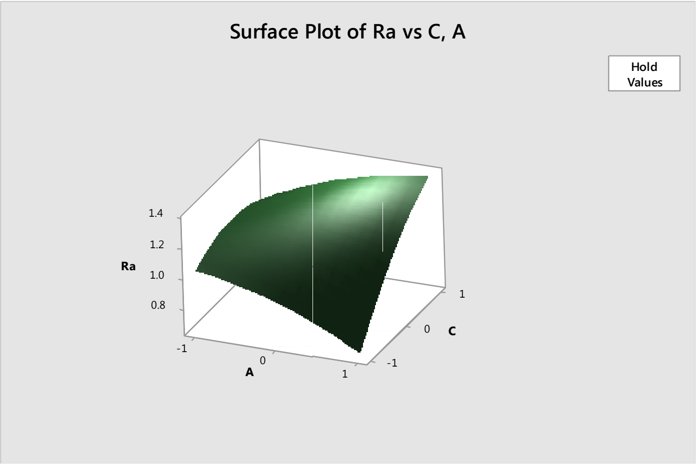

Figure.7. Surface Plot of Ra VS C, A

Fig. 8 shows the interaction and direct effects of depth of cut and speed on the surface roughness. The above figure evidenced that the depth of cut and feed on the surface roughness of tuning process has a significant effect. Fig. 8 shows that at highest level of feed (i.e. 0.150 mm/rev) with increase in depth of cut (i.e. 0.2 to 0.4mm) have a significant effect on surface roughness.

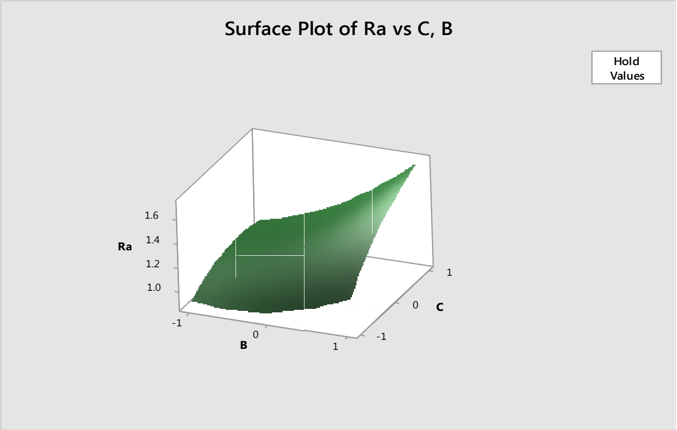

Figure.8. Surface Plot of Ra VS C, B

The contour plot for the response, surface roughness is shown in Fig. 9, 10, and 11. Contour plots show that the surface roughness increases with increase in feed. Roughness increases with the increase of depth of cut.

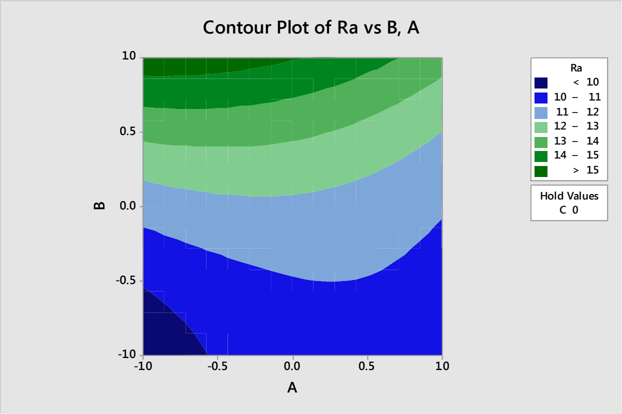

Figure.9. Contour Plot of Ra VS B, A

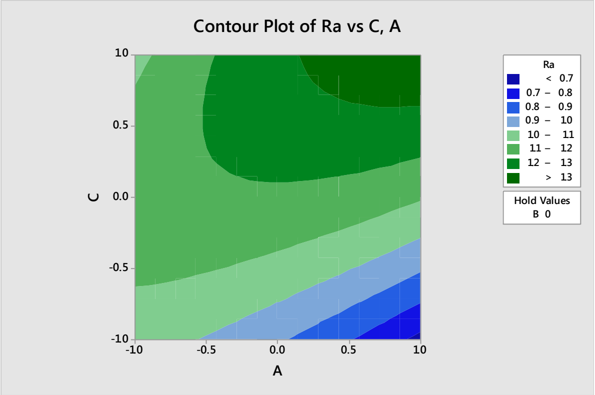

Figure.10. Contour Plot of Ra vs C, A

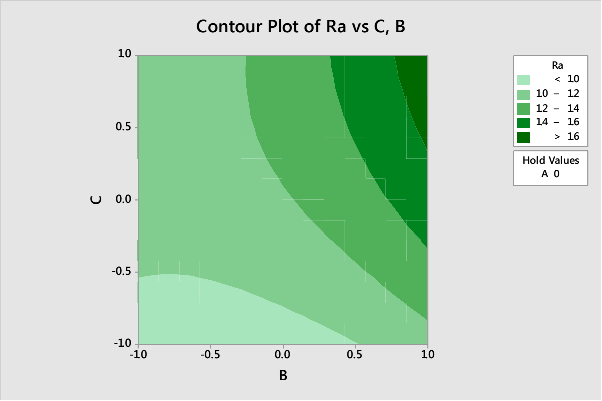

Figure.11. Contour Plot of Ra VS C, B

4.2.1. Regression Equation

Surface Roughness = 1.1825 – (0.0160 * Speed) + (0.2240 * Feed) + (0.1820* Depth of cut) – (0.0564 * Speed^2) + (0.1036 * Feed^2) – (0.0864 * Depth of cut^2) - (0.0950 * Speed*Feed) + (0.1700 * Speed*Depth of cut) + (0.1150 * Feed*Depth of cut) - (2)

Table.11. Predicted Response for New Design Points Using Model for Ra

POINT	FIT	SE FIT	95% CI	95% PI
1	0.94345	0.141190	(0.628864, 1.25804)	(0.470444, 1.41647)
2	1.14218	0.111075	(0.894691, 1.38967)	(0.710877, 1.57349)
3	1.18255	0.054499	(1.06111, 1.30398)	(0.809024, 1.55607)
4	1.72345	0.141190	(1.40886, 2.03804)	(1.25044, 2.19647)
5	0.76145	0.141190	(0.446864, 1.07604)	(0.288444, 1.23447)
6	0.78945	0.141190	(0.474864, 1.10404)	(0.316444, 1.26247)
7	1.18255	0.054499	(1.06111, 1.30398)	(0.809024, 1.55607)
8	1.60545	0.141190	(1.29086, 1.92004)	(1.13244, 2.07847)
9	0.73745	0.141190	(0.422864, 1.05204)	(0.264444, 1.21047)
10	1.18255	0.054499	(1.06111, 1.30398)	(0.809024, 1.55607)
11	1.18255	0.054499	(1.06111, 1.30398)	(0.809024, 1.55607)
12	1.23545	0.141190	(0.920864, 1.55004)	(0.762444, 1.70847)
13	1.06218	0.111075	(0.814691, 1.30967)	(0.630877, 1.49349)
14	1.18255	0.054499	(1.06111, 1.30398)	(0.809024, 1.55607)
15	1.11018	0.111075	(0.862691, 1.35767)	(0.678877, 1.54149)
16	1.35145	0.141190	(1.03686, 1.66604)	(0.878444, 1.82447)
17	1.27818	0.111075	(1.03069, 1.52567)	(0.846877, 1.70949)
18	1.51018	0.111075	(1.26269, 1.75767)	(1.07888, 1.94149)
19	1.18255	0.054499	(1.06111, 1.30398)	(0.809024, 1.55607)
20	0.91418	0.111075	(0.666691, 1.16167)	(0.482877, 1.34549)

4.2.2. Response Optimization: Surface Roughness

Table.12. Parameters of Response optimization

GOAL	Lower	Target	Upper	Weight	Import
MINIMUM	0.58	0.58	1.86	1	1

Global Solution: A= 1, B= -0.0646, C= -1
Predicted Response: Ra = 0.6713,
Desirability = 0.92864
Composite Desirability = 0.9286

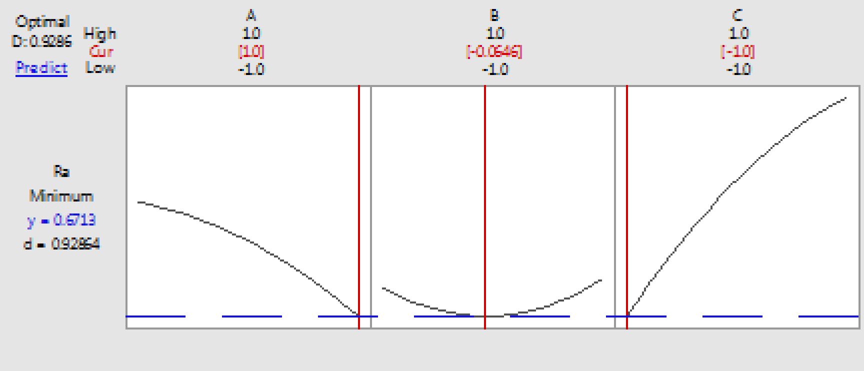

Figure.12. Optimization plot

V. CONCLUSIONS

The Consequences of the experiment data is used for predicting the outcome of assorted input machining parameters such as cutting speed, feed and depth of cut on the surface roughness when machining Aluminium 6061.

4.3. Conclusion with Taguchi

The following conclusions can be drawn based on the analysis conducted at three levels by employing Taguchi technique to determine the optimal level of process parameters.

1. The increase in cutting speed causes decrease in surface roughness and hence tends to improve the finish.
2. The Increase in depth of cut increases surface roughness.

3. The increase in feed rate increases surface roughness.
4. The optimal combination process parameter for minimum surface roughness is obtained at 2100 rpm, 0.1 mm/rev and 0.2 mm.
5. ANOVA table and F-test shows that the percentage contribution of feed is maximum followed by depth of cut. The spindle speed has very less effect on the response in this experiment.
6. From plots for S/N ratio, the ideal conditions for least surface roughness (Ra) are speed at level 3 (2100 rev/min), feed at level 1 (0.1 mm/rev) and depth of cut at level 1 (0.2 mm).
7. Taguchi gives systematic simple approach and efficient method for the optimum operating conditions.

4.4. Conclusion with Response Surface Methodology

The following conclusions can be drawn based on the analysis conducted at three levels by employing Response Surface Methodology to determine the optimal level of process parameters.

1. A quadratic equation is developed and projected.
2. Feed rate has the strongest effect on the surface roughness among the selected parameters. It is directly proportional to the response.
3. Surface roughness is directly proportional to depth of cut.
4. Surface roughness is affected by factors in order as feed followed by depth of cut.
5. The change in feed rate has significant effect on surface roughness at lowest cutting speed (i.e. 1700).
6. The change in depth of cut has a significant effect on surface roughness at highest level of feed (i.e. .150mm/rev).

4.5. Comparison of Conclusion from Taguchi and RSM

1. The analysis of the results for surface roughness shows that the techniques, Taguchi method and Response surface methodology, give similar results. Taguchi's method revealed that feed is the most significant factor followed by depth of cut and speed. The 3D surface plots of Response surface methodology also revealed that feed has very significant effect in surface roughness. The lowest value of surface roughness in the given range of parameters as depicted by graphs is feed (0.1mm/rev), depth of cut (0.2mm) and speed (2100 rpm).
2. Significance of interactions and square terms of parameters is more clearly predicted in Response Surface Methodology. The Response Surface Methodology shows significance of all possible combinations of interactions and square terms. Whereas in Taguchi's technique only two factor interactions (AB, AC and BC) can be studied. This is because of the fact that the interactions between control factors are aliased with their main effects.
3. Response surface methodology technique can model the response in terms of significant parameters, their interactions and square terms. This facility is not provided by Taguchi's technique.
4. 3D surfaces generated by Response surface methodology (Figs. 6–8) can help in visualizing the effect of parameters on response in the entire range specified whereas Taguchi's technique gives the average value of response at given level of parameters (Figs. 1-2).
5. Optimization plot as shown in Fig. 12 obtained from Response surface methodology is not a feature of Taguchi technique. Thus Response surface methodology is a better tool for optimization and can better predict the effect of parameters on response.

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