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Analysis and Optimization of CNC Turning Process Parameters for Hard (62-64 HRC) AISI M2 to Minimize Surface Roughness

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Abstract: In the present investigation, the influence of machining parameters including cutting speed, feed rate and depth of cut on surface roughness (Ra) in a dry turning environment for hard AISI M2 are investigated using the Taguchi method and analysis of variance (ANOVA). A three level, three parameter design of experiment, the L27 orthogonal array using Minitab 17 software, the single to noise (S/N) ratio are employed to study the performance characteristic in the turning of hard AISI M2 by taking nose radius of the PCBN insert (Kennametal) of 0.8mm.The analysis of variance (ANOVA) is applied to investigate the percentage contribution of each machining parameters.The results are verified by taking confirmation experiments.The present study indicates that cutting speed is the most influencing factor for surface roughness.
Keywords: CNC turning, Minitab17, Surface roughness, Taguchi method, Hard AISI M2, PCBN insert

I. INTRODUCTION

In the present era, the technology related to CNC has advanced significantly, in order to meet the advance needs in manufacturing fields, especially in the precision machining industries. The turning process is a most common machining process because it is involved in near about every manufacturing industry. In the turning process, one of the most important quality parameters is a surface finish. In order to improve the quality of turned components, it is very important to choose a proper set of machining parameters such as cutting speed, feed rate, depth of cut with proper insert material and nose radius.

E. Daniel Kirby, Zhe Zhang et.al [3] applied the Taguchi parameter design method to optimizing the surface finish in a turning operation for 6061-T6 aluminum alloy rod. They selected machining parameters such as spindle speed, feed rate, depth of cut, and tool nose radius to optimize the turning operation. They had taken noise factors such as varying room temperature, as well as the use of more than one insert of the same specification, which introduced tool dimension variability. They conducted a total of thirty-six experimental trials using an orthogonal array, and the ideal combination of control factor levels was determined for the optimal surface roughness and signal to noise ratio. They concluded that this method was efficient as well as effective in determining the best turning parameters for the optimal surface roughness. Krupal Pawar, R. D. Palhade [7] studied the effect of insert nose radius and machining parameters including cutting speed, feed rate, and depth of cut on surface roughness(Ra) and material removal rate(MRR) in a turning of HSS(M2).They adopted method for study were the Taguchi method and analysis of variance (ANOVA).They selected process parameters for study was cutting speed, feed rate, depth of cut, and nose radius (0.4mm, 0.6mm,1.2mm).Single to noise ratios were employed to study the performance characteristics in the turning of HSS(M2).The analysis of variance was applied to investigate the percentage influence of each machining parameters while CNC turning of HSS(M2) material. They performed all experimental trials without cutting fluid and at a constant spindle speed 2800 rpm.They concluded that feed rate and nose radius are the most significant factors in case of material removal rate and surface roughness for turning of HSS (M2) material.Suha K Shihab, Zahid A Khan et.al [8] investigated the influence of cutting speed, feed rate, and depth of cut on surface integrity defined in terms of surface roughness and micro hardness in dry hard turning process. They selected hardened alloy steel AISI 52100 as specimen material and it machined on a CNC lathe with coated carbide tool under different settings of cutting parameters. They employed a central composite design (CCD) of experiment to collect experimental data for surface roughness and micro hardness. They employed analysis of variance (ANOVA) to determine significance of the cutting parameters. They applied response surface methodology (RSM) to determine optimal values of cutting parameters and checked the validity of assumptions by taking several diagnostic tests. They concluded that feed rate is the dominant factor affecting the surface roughness whereas the cutting speed is found to be the dominant factor affecting the micro-hardness. They also conclude that within the range investigated, good surface integrity is achieved when feed rate and depth of cut are near their low levels and

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cutting speed is at high level. Jeffrey D. Thiele, Shreyes N. Melkote [5] investigated the effects of tool cutting edge geometry and workpiece hardness on the surface roughness and cutting forces in the finish hard turning of AISI 52100 steel. They used cubic boron nitride (CBN) inserts with various cutting edge preparations and hardened AISI 52100 steel bars as the cutting tools and workpiece material, respectively. They concluded that the effect of edge geometry on the surface roughness and cutting forces is statistically significant and large edge hones result in higher average surface roughness values than small edge hones, due to increase in the extent of ploughing compared to shearing. Their study revealed that the large edge hones are responsible for higher forces in the axial, radial, and tangential directions than small edge hone. They also concluded that the effect of workpiece hardness on the axial and radial components of force is significant, particularly for large edge hones.E. Aslan [2] studied the performance and wear behavior of different cutting tools in end milling of X210 Cr12 cold-work tool steel hardened to 62 HRC. His purpose was to investigate the wear of TiCN coated tungsten carbide, TiCN +TiAlN coated tungsten carbide, TiAlN coated cermet, mixed ceramic with Al2O3+TiCN and cubic boron nitride (CBN) tools. He selected response factors for investigation such as surface finish and tool flank wear. He used a JSM 5600 (30 kW) scanning electron microscope to measure tool flank wear. He used a Mitutoyo Metusurf 310 equipment to measure the surface roughness values. The investigator concluded that CBN tool exhibited the best cutting performance in terms of both flank wear and surface finish and the highest volume of metal removal was obtained with CBN tool.

On the strength of the evaluation of work done by former investigators, it is found that a huge amount of research work has been carried out for modeling, simulation and parametric optimization of surface properties of the material in turning operation. The problems related to tool life, tool wear and cutting forces are also addressed to. However no work is found for optimizing the surface characteristics for hard (62-64 HRC) AISI M2 material using PCBN 0.8 mm nose radius insert in the dry turning environment.

This investigation demonstrates details of Taguchi optimization technique to optimize the surface roughness. The main objective of present study is to find out process parameter’s set which will give minimum surface roughness value while turning hard AISI M2 on a CNC machine.

II. DESIGN OF EXPERIMENT

The design of experiment is an offline method to inspect quality of any manufacturing process. There are a number of methods to design experiments such as factorial design, response surface design, mixture design, and Taguchi design. Taguchi method is the oldest method of optimization and is industrial accepted method.It is powerful tool to design high-quality system.It follows systematic, simple and efficient approach to optimize designs for performance, quality and cost.[6]

Table i

Control factors with levels

Levels	Control Parameters		
	Cutting Speed (mm/min)	Feed Rate (mm/rev)	Depth of Cut (mm)
L1	100	0.1	0.4
L2	140	0.15	0.5
L3	180	0.2	0.6

Taguchi method uses Signal-to-Noise ratios to measure the performance characteristics. In the present research, work experiment is designed by Taguchi technique, which uses an orthogonal array to investigate the entire parametric space with a limited number of experimental trials. The three machining parameters considered in this study are cutting speed, feed rate, and depth of cut. The nose radius 0.8mm is taken constantly in this investigation because it gives better performance as per the previous study was done on this material processing [7].All machining parameters are set at three different levels (see Table 1).The selection of particular orthogonal matrix is done with help of MINITAB 17 software.In this software for three parameters available orthogonal arrays are L9, L18, and L27.In the present study, the L27 orthogonal array is selected to find more accurate optimum value of response characteristic.In this research work, the interactions between factors are considered.The response variables chosen for the present investigation is surface roughness. The smaller is the better quality characteristic is employed for surface roughness.[6]

Condition of S/N ratio for surface roughness is smaller is better

$$S/N = -10 \times log(\Sigma(Y^2)/n) \quad (1)$$

Where, S/N-Signal to Noise Ratio, Yi – i^{th} observed value of the response, n - Number of observations in a trial, Y - Average of observed responses values. After finalizing control factors and their levels, the design of orthogonal matrix is prepared using MINITAB 17 statistical software which is shown in below.

Table II
Design of experiment by taguchi's l_{27} orthogonal array and s/n ratios

Expt. No.	Cutting Speed	Feed Rate	Depth of Cut	Ra1(μm)	Ra2(μm)	Ra3(μm)	Ra Mean	S/N Ratio (dB)
1	100	0.1	0.4	0.37	0.73	0.42	0.51	5.906
2	100	0.1	0.5	0.87	0.61	0.65	0.71	2.975
3	100	0.1	0.6	0.88	0.86	1	0.91	0.787
4	100	0.15	0.4	0.91	0.9	0.93	0.91	0.787
5	100	0.15	0.5	0.91	0.91	0.79	0.87	1.210
6	100	0.15	0.6	1.18	1.16	1.06	1.13	-1.087
7	100	0.2	0.4	0.7	0.67	0.66	0.68	3.393
8	100	0.2	0.5	0.89	0.99	0.8	0.89	0.980
9	100	0.2	0.6	0.52	0.47	0.47	0.49	6.255
10	140	0.1	0.4	0.29	0.38	0.58	0.42	7.604
11	140	0.1	0.5	0.36	0.38	0.39	0.38	8.481
12	140	0.1	0.6	0.51	0.51	0.49	0.50	5.963
13	140	0.15	0.4	0.36	0.31	0.31	0.33	9.718
14	140	0.15	0.5	0.35	0.36	0.37	0.36	8.874
15	140	0.15	0.6	0.56	0.55	0.58	0.56	4.985
16	140	0.2	0.4	0.27	0.29	0.26	0.27	11.266
17	140	0.2	0.5	0.37	0.45	0.37	0.40	8.031
18	140	0.2	0.6	0.46	0.53	0.48	0.49	6.196
19	180	0.1	0.4	0.84	0.83	0.98	0.88	1.078
20	180	0.1	0.5	0.34	0.39	0.32	0.35	9.119
21	180	0.1	0.6	0.69	0.35	0.38	0.47	6.497
22	180	0.15	0.4	0.28	0.3	0.24	0.27	11.266
23	180	0.15	0.5	0.31	0.36	0.36	0.34	9.286
24	180	0.15	0.6	0.53	0.56	0.58	0.56	5.088
25	180	0.2	0.4	0.45	0.28	0.37	0.37	8.715
26	180	0.2	0.5	0.41	0.39	0.42	0.41	7.815
27	180	0.2	0.6	0.58	0.7	0.55	0.61	4.293

III. EXPERIMENTATION

A. Specimen Material

The three cylindrical hard (62-64 HRC) specimens of AISI M2 are selected for experimental trials.The specimen size is taken as Ø59×350mm.The chemical composition of AISI M2 specimen material were C-0.86/0.96, Cr-3.8/4.5, Mo-4.9/5.5, W-6.0/6.75, V-1.7/2.2 [4] and the properties of AISI M2 are density-8.028×10-3g/mm3, melting point-46800, hardness-62-65 HRC, compressive yield strength-3250 Mpa, Poisson's ratio-0.27-0.30, elastic modulus-190-210 Gpa [4].The application of AISI M2 material involves manufacturing of twist drills, reamers, taps and cold forming tools such as extrusion rams and dies and also to prepare plastic molds with elevated wear resistance and screw[4].

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Figure 1 Specimens of AISI M2 Material after Experimentation

B. Cutting Tool and Tool Holder

In present work, the cutting tool used for turning AISI M2 hard specimen is rectangular shape PCBN CNMG160408 insert which is shown in Figure 2.

Figure 2 Insert Geometry

Figure 3 Tool Holder

The clearance angle of the insert is zero.The inscribed circle size is 9.5mm and thickness is 5mm.The tool holder used during experimentation is PCLNR 2525M12 which is shown in Figure3.The properties of cutting tool material are high melting point, high thermal conductivity, low coefficient of thermal expansion.

C. Experimental Unit and Procedure

The CNC machine used in this experimentation is ACE make and model simple turn 5075 with Siemens 802controller. The CNC lathe has a maximum spindle speed of 2000 rpm and a power of 380 v/4.5v.The CNC lathe has 250 mm maximum turning diameter and 700 mm maximum turning length [1]. The all experimental trials are conducted without coolant and as per sequence of design of OA.

Figure 4 Experimental Unit (VIIT, Pune)

Figure 5 Surface Roughness Testing

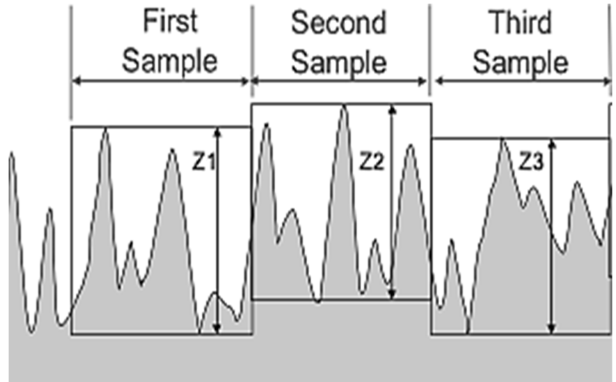

Figure 6 Surface Roughness Measurements at Three Places

Table III
Specification of surface roughness testing machine (surtronic duo)[9]

Parameter	Value	Parameter	Value
Gauge range	200µm (0.008in)	Battery life	5,000 operations minimum
Accuracy	5% of reading + 0.1µm (4µin)	Parameter results Code 112/3115-01	Ra, Rz, Rv, Rp, Rt
Pick up type	Piezoelectric	Parameter: Ra	Range 40 µm Resolution 0.01 µm
Gauge force	200mg		
Stylus	Diamond, Radius 5µm (200µin)	Parameter: Rz, Rv, Rp, Rt	Range 199 µm Resolution 0.1 µm
Cut off value	0.8mm ± 15% (0.03in ± 15%)		
Filter	2CR		
Traverse length	5mm (0.2in)		
Traverse speed	2mm/sec (0.08in/sec)		
Display units	µm / µin		

The turning process is done for three specimens as per design of orthogonal array.The slot of 2.5 mm is done on specimens. After machining, the surface roughness is measured in the feed direction using Surtronic Duo (see Figure 5) whose L.C is 0.001µm.A photograph of the surface roughness measurement setup is shown in Figure 5.The set of three readings is taken on each slot to measure surface roughness (Ra). After getting set of three readings, average for each reading is calculated (see Table II).

IV. OPTIMIZATION, ANALYSIS AND MODELING FOR SURFACE ROUGHNESS

A. Optimum Predicted Surface Roughness

The optimum value of surface roughness can be calculated by manually hand calculation as well as using MINITAB 17 software.
Let Ra'= average results for 27 runs of response value = 0.53 µm.

$$Ra' = \frac{\sum_{i=1}^{27} Ra}{27} \qquad (2)$$

$$\text{Ra(Optimum)} = Ra' + (A_{n1} - Ra') + (B_{n2} - Ra') + (C_{n3} - Ra') + (D_{n4} - Ra') \text{ [Ross,1988]} \qquad (3)$$

Where A_{n1}, B_{n2}, C_{n3} and D_{n4} are corresponding mean values of optimum points indicated in S/N graph.
= 0.53 + (0.4119-0.53) + (0.5111- 0.53) + (0.5152- 0.53)Optimum surface roughness (Ra) by manual hand calculation = 0.3782 µm.
Now,calculating optimum surface roughness by using MINITAB17 software.

So,optimum surface roughness (Ra) predicted by MINITAB 17 software = 0.284568 µm.

From the above calculation, the conclusion can be drawn that there is a minor error (0.009 µm) between manually and software predicted optimum surface roughness value and therefore it is proved that the optimum surface roughness is accurately calculated.

Table IV
Response table for means

Level	Cutting Speed	Feed Rate	Depth of Cut
1	0.7893(A1)	0.5704(B1)	0.5152(C1)
2	0.4119(A2)	0.5933(B2)	0.5230(C2)
3	0.4737(A3)	0.5111(B3)	0.6367(C3)
Delta	0.3774	0.0822	0.1215
Rank	1	3	2

Table V
Response table for signal to noise ratios (smaller is better)

Level	Cutting Speed	Feed Rate	Depth of Cut
1	2.356	5.379	6.637
2	7.902	5.570	6.308
3	7.017	6.327	4.331
Delta	5.546	0.948	2.306
Rank	1	3	2

Table IV and Table V shows that level such as A2(140 mm/min), B3(0.20 mm/rev),and C1(0.4mm) is optimum level of process parameter which gives optimum surface roughness and surface roughness is more influenced by the cutting speed(rank 1).

B. *Analysis of Variance for Surface Roughness by MINITAB17 Software*

The purpose of the analysis of variance (ANOVA) is to investigate which parameter significantly affects the response factor most. The method of manually ANOVA calculation is given below.

In ANOVA calculations, the degree of freedoms for all factors needs to be obtained first:

Total degree of freedom, f_T = Number of trials -1

For factor A degree of freedom, f_A = Numbers of levels – 1= k_A-1 (4)

Similarly, F_B, F_C, F_D can be calculated.

For Error, $f_e = f_T - (f_A + f_B + f_C + f_D)$. (5)

Sum of squares for all factors is then calculated using formula is shown below:

For factor A, $$s_A = \frac{\left(\sum A_1\right)^2}{k_A} + \ldots\ldots + \frac{\left(\sum A_4\right)^2}{k_A} - \frac{(z_{a1} + z_{a2} + \ldots + z_{aN})^2}{N} \quad (6)$$

Similarly S_B, S_C, S_D can be calculated.

The total sum of square is calculated as follows:

$$s_T = (z_{a1}^2 + z_{a2}^2 + \ldots + z_{aN}^2) - \frac{(z_{a1} + z_{a2} + \ldots + z_{aN})^2}{N} \quad (7)$$

Now the total sum of error, $S_e = S_T - (S_A + S_B + S_C + S_D)$. (8)

The values of variances for all factors are then calculated.

For factor A, $V_A = S_A/f_A$. (9)

Similarly V_B, V_C, V_D can be calculated.

For variance error = $V_e = S_e/f_e$. (10)

Then F-ratio, F for all factors are calculated afterwards.

For factor A, $F_A = V_A/V_e$. (11)

However F_A, F_B, F_C and F_D cannot be determine as $V_e = 0$.

Last but not least, percentage contributions for all factors are calculated by following way.

For factor A, $P_A = S_A/S_T \times 100$. Similarly P_B, P_C , and P_D can be calculated.[6] (12)

Table VI
application of anova for s/n ratio

Source	DOF	Seq.SS	Adj.SS	Adj.MS	F	P
Cutting Speed	2	159.798	159.798	79.899	11.52	0.004
Feed Rate	2	4.530	4.530	2.265	0.33	0.731
Depth of Cut	2	28.004	28.004	14.002	2.02	0.195
Cutting Speed* Feed Rate	4	29.943	29.943	7.486	1.08	0.427
Cutting Speed * Depth of Cut	4	17.718	17.718	4.429	0.64	0.650
Feed Rate * Depth of Cut	4	22.574	22.574	5.644	0.81	0.551
Residual Error	8	55.484	55.484	6.936		
Total	26	318.051				
S = 2.634 R-Sq. = 82.6% R-Sq.(adj.) = 43.3%						

From Table VI, it can be concluded that cutting speed is the most significant factors which affect the surface roughness.

C. Regression Analysis for Surface Roughness by MINITAB17 Software

The correlation between the process parameters and response factor such as surface roughness are obtained using regression analysis technique. The regression equation is as follows:

Surface Roughness (Ra) = 1.10 - 0.00418 (Cutting Speed) - 0.77(Feed Rate) + 0.441(Depth of Cut) (13)

Weighted analysis using weights in Ra (Average) is as follows:

Table VII
predictor's coefficient value

Predictor	Coefficient	Sec. Coefficient	T- value	P- value
Constant	1.0987	0.3463	3.17	0.004
Cutting Speed	-0.004184	0.001238	-3.38	0.003
Feed Rate	-0.769	1.046	-0.74	0.470
Depth of Cut	0.4408	0.5080	0.87	0.394
S = 0.162891 R-Sq. = 35.4% R-Sq.(adj.) = 27.0%				

Table VIII
Analysis of variance for regression

Source	DOF	SS	MS	F- value	P-value
Regression	3	0.33420	0.11140	4.20	0.017
Regression Error	23	0.61027	0.02653		
Total	26	0.94448			

V. RESULTS AND DISCUSSIONS

A. Effect of Cutting Speed on Surface Roughness

Figure 8 illustrates the evolution of surface roughness according to the cutting speed. Figure 8 and Figure 9 shows that the surface roughness initially decreases with increase in cutting speed up to 140 mm/min and then increases with increase in cutting speed up to 180 mm/min.Figure 6 shows that at 140 mm/min, the surface roughness is at an optimum level means we will get the better surface finish at 140 mm/min.The cutting speed is a most influencing factor for the surface roughness value and the second one is a depth of cut.

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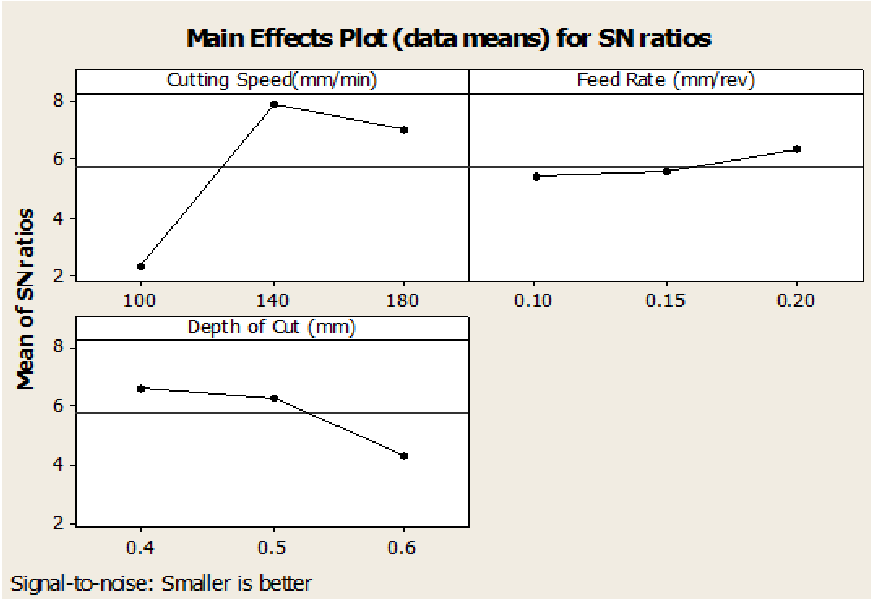


Figure 7 Main Effects Plot for SN Ratios

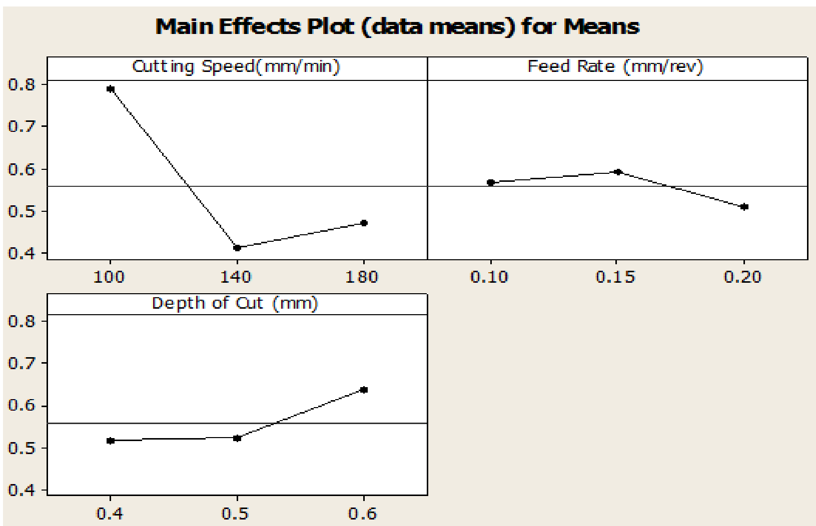


Figure 8 Main Effects Plot for SN Ratios

B. Effect of Feed Rate on Surface Roughness

Figure 8 illustrates the evolution of surface roughness according to the feed rate. Figure 8 and Figure 9 (a) shows that the surface roughness initially increases slowly with increase in feed rate up to 0.15 mm/rev and then decreases sharply with increase in feed rate up to 0.2 mm/rev. Figure 7 shows that at 0.2 mm/rev, the surface roughness is at an optimum level means we will get better finishing at 0.2mm/rev feed rate.

C. Effect of Depth of Cut on Surface Roughness

Figure 8 shows the evolution of surface roughness according to the depth of cut. Figure 8 and Figure 9 (b) shows that the surface roughness initially increases slightly with the increase in the depth of cut up to 0.5 mm and then increases sharply with increase in depth of cut up to 0.6 mm.Figure 7 shows that at 0.4 mm, the surface roughness is at an optimum level means we will get better finishing at 0.4 mm depth of cut.

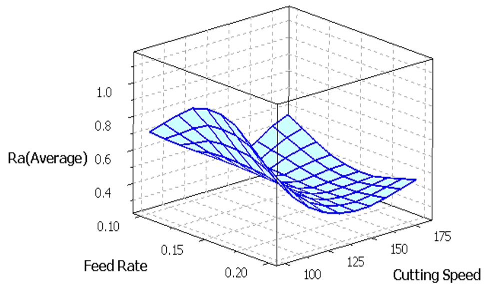


Figure 9 (a) Surface Plot to Study Effect of Cutting Speed and Feed Rate on a Surface Roughness

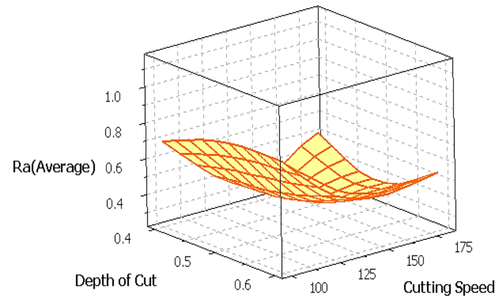
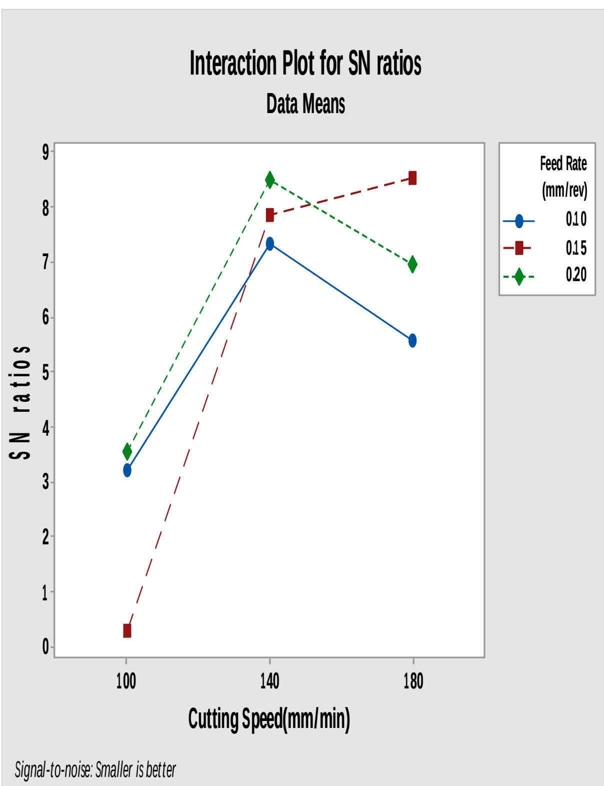


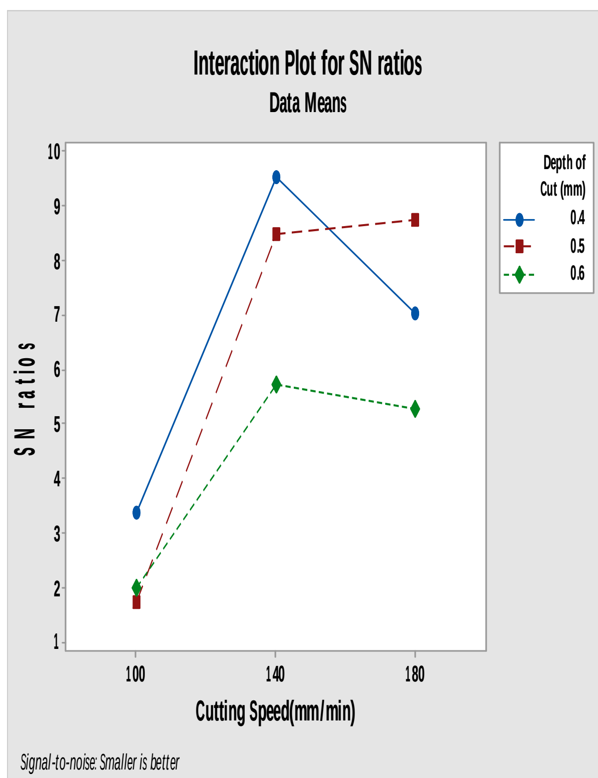
Figure 9 (b) Surface Plot to Study Effect of Cutting Speed and Depth of Cut on a Surface Roughness

D. Interaction Plots for Signal to Noise Ratios of Surface Roughness

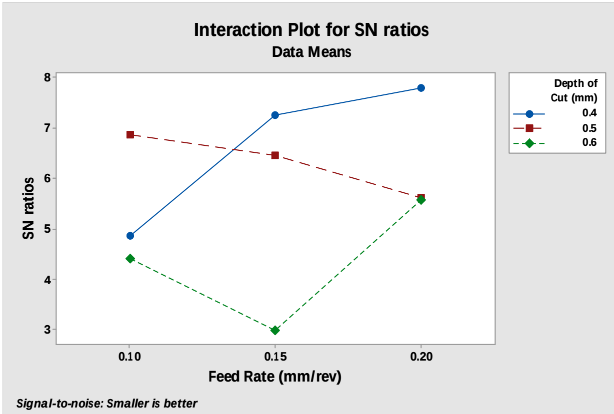
Figure 10 shows the plots for the signal to noise ratios of surface roughness with normal probability plot. In Figure 10 (a) the green dotted line shows 0.20 mm/rev feed rate, the blue continuous line shows 0.10 mm/rev feed rate, and the red dotted line shows 0.15 mm/rev feed rate.The feed rate 0.20 mm/rev gives the maximum value of the signal to noise ratio at cutting speed of 140 mm/min means interaction of these two factors gives optimum surface roughness value. In Figure 10 (b) the green dotted line shows 0.6 mm depth of cut, the blue continuous line shows 0.10 mm depth of cut and red dotted line shows 0.5 mm depth of cut.The depth of cut of 0.4 mm gives the maximum value of the signal to noise ratio at cutting speed of 140 mm/min means interaction of these two factors gives optimum surface roughness value.In Figure 10 (c) the green dotted line shows 0.6 mm depth of cut, the blue continuous line shows 0.10 mm depth of cut and the red dotted line shows 0.5 mm depth of cut.The depth of cut of 0.4 mm gives the maximum value of the signal to noise ratio at a feed rate of 0.20 mm/rev means interaction of these two factors gives optimum surface roughness value.Figure 10 (d) shows the probability plot for the response which is the signal to noise ratio.It shows that all signal to noise ratio values follows the straight line means our model is statically good.



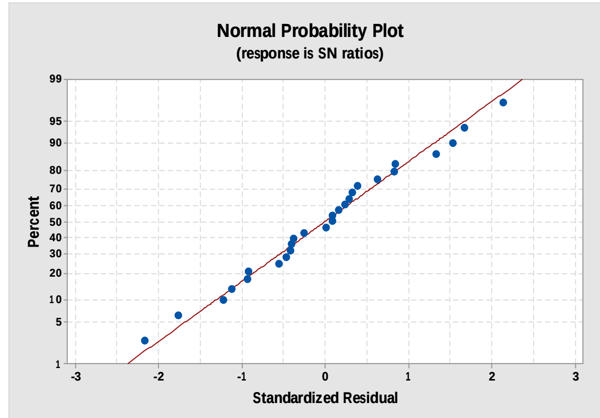
(a)



(b)



(c)



(d)

Figure 10 Interaction Plots for Single to Noise Ratios of Surface Roughness with the Normal Probability

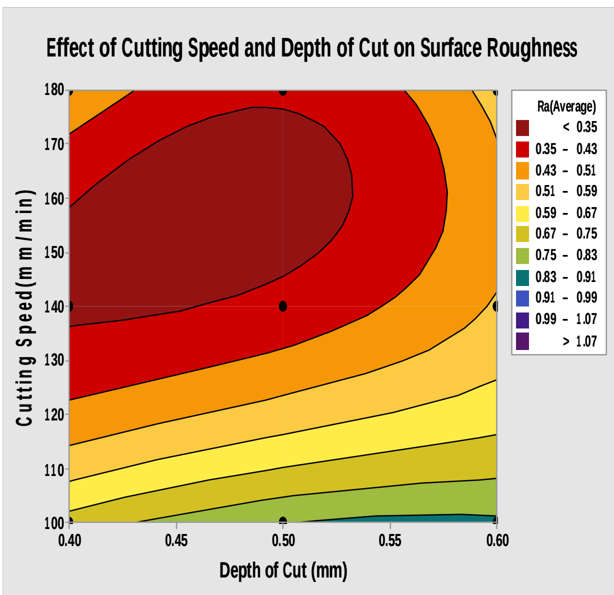


Figure 11 (a) Counter Plot to Study Influence of Cutting Speed and Depth of Cut on a Surface Roughness

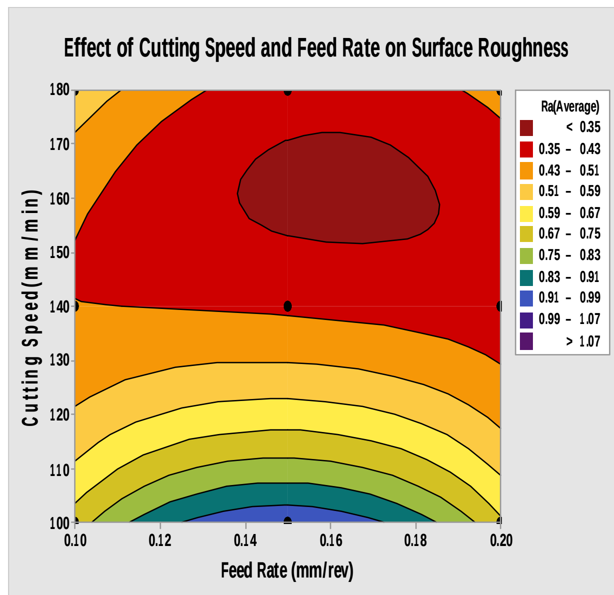


Figure 11 (b) Counter Plot to Study Influence of Cutting Speed and Feed Rate on a Surface Roughness

Figure 11 (a) shows the counter plot to investigate the influence of cutting speed and depth of cut on a surface roughness. It shows that the surface roughness value is minimum in the area acquired by cutting speed range from 140 mm/min to 160 mm/min and depth of cut range from 0.40 mm to 0.50 mm and Figure 11 (b) shows that shows the counter plot to investigate the influence of cutting speed and feed rate on a surface roughness.It shows that the surface roughness value is minimum in the area acquired by cutting speed range from 140 mm/min to 170 mm/min and feed range from 0.14 mm/rev to 0.18 mm/rev.

VI. VALIDATION OF RESULT

In order to validate the results obtained six confirmation experiments are conducted for the response characteristic at optimal levels of the process variables.The average values of the characteristics are obtained and compared with the predicted values.The results are given in Table IX. The value of surface roughness obtained through confirmation experiments are within the 95% of CI of respective response characteristic. It is to be pointed out that these optimal values are within the specified range of process variables.

Table IX
Confirmation test for surface roughness (ra)

Sr.No.	Optimum Value of Parameters	Optimum Level of Parameters	Optimum Predicted Value of Ra (µm)	Optimum Experimental Value of Ra (µm)	Error Ra (µm)
1.	Cutting Speed = 140 mm/min	A2	0.37	0.48	0.11
2.	Feed Rate = 0.2 mm/rev	B3	0.37	0.47	0.10
3.	Depth of Cut = 0.4 mm	C1	0.37	0.46	0.09
4.			0.37	0.45	0.08
5.			0.37	0.48	0.11
6.			0.37	0.47	0.10
		Average	0.37	0.4683	0.098

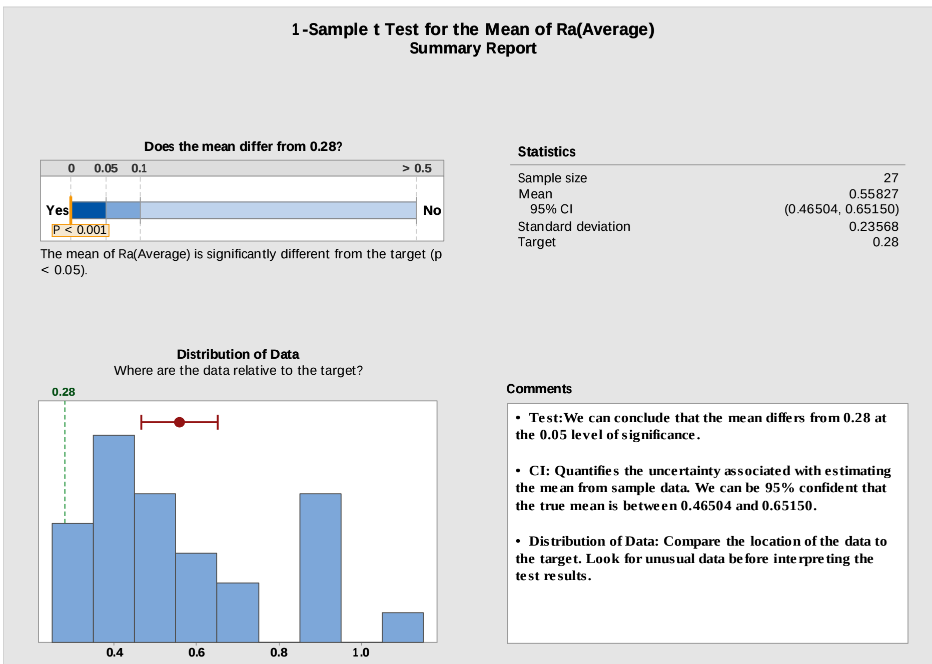


Figure 12 1-Sample t Test for Mean of Surface Roughness

Figure 12 shows the diagnosis test performs with help of MINITAB17 software to find confidence interval and it shows that the value of surface roughness obtained through confirmation experiments are within the 95% of CI of respective response characteristic.i.e.$0.46504 \leq 0.4683 \leq 0.65150$.

VII. CONCLUSIONS

The turning tests are conducted on the hard AISI M2 specimens using the PCBN insert with 0.8 mm nose radius.The influences of cutting speed, feed rate, and depth of cut are investigated by Taguchi and ANOVA on the surface roughness. Based on the results obtained, the following conclusions are drawn:

It is observed that the cutting speed and depth of cut are two most significant parameters those affect the surface roughness most as per the analysis of variance (ANOVA) while hard turning of AISI M2 on a CNC machine.

The optimum level of process parameters is A2, B3, and C1 with a 0.8 mm nose radius of the PCBN insert (i.e. cutting speed= 140 mm/min, feed rate= 0.2 mm/rev, and depth of cut = 0.4mm) for the hard turning of AISI M2 on a CNC machine.

The optimum value of surface roughness at optimum level of machining parameters is 0.4683µm (Experimental Value of Surface Roughness).

VIII. ACKNOWLEDGEMENTS

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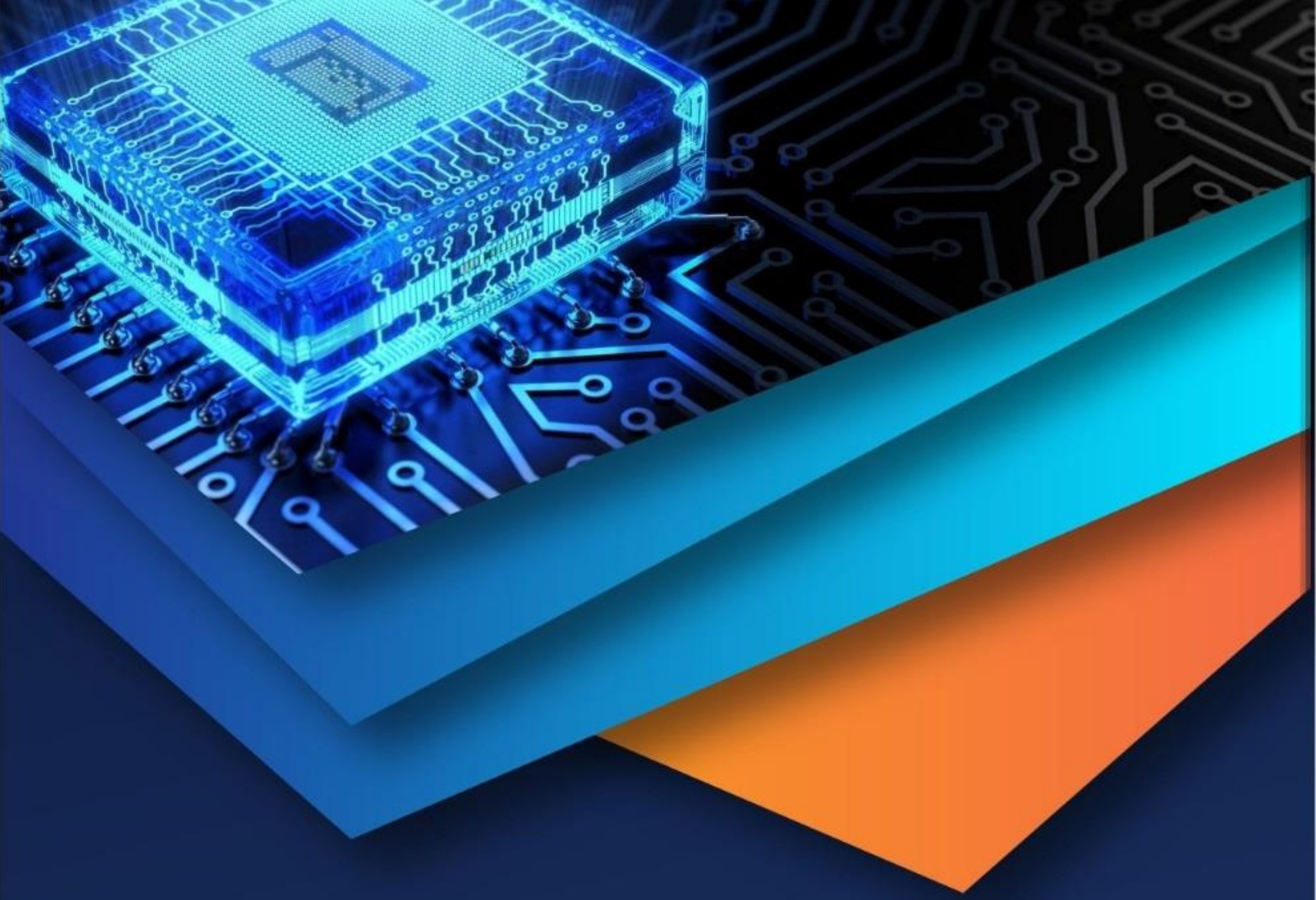

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