

The Eurasia Proceedings of Science, Technology, Engineering and Mathematics (EPSTEM), 2026

Volume 41, Pages 27-37

ICRETS 2026: International Conference on Research in Engineering, Technology and Science

Determination of the Optimum Cutting Parameters on Surface Roughness in Turning AISI 4340 Steel

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Abstract: This study investigates the effects of fundamental machining parameters including insert types on the surface roughness (R_a) obtained during finish turning of AISI 4340 steel. External turning experiments were conducted on a Spinner TC65 CNC turning centre using a Taguchi L9 orthogonal array. Three different inserts like uncoated carbide, coated carbide, and CBN, respectively, were used to find out optimal conditions. Analysis of variance was carried out and the multiple linear regression equation was established. The results indicated that measured R_a values ranged from 0.361 to 2.411 μm . Feed rate was the dominant factor affecting on R_a , followed by cutting speed/insert type, and depth of cut. The optimal conditions based on the S/N response were determined as a cutting speed of 230 m/min, a feed rate of 0.08 mm/rev, a depth of cut of 1.2 mm, and the CBN insert. The regression model explained the R_a response with $R\text{-sq} = 98.05\%$, $R\text{-sq}(\text{adj}) = 96.10\%$, and $R\text{-sq}(\text{pred}) = 90.09\%$. Moreover, ANOVA results revealed that feed rate was statistically significant ($p < 0.001$) by indicating the highest contribution to the variation of R_a values. Cutting speed was also statistically significant ($p = 0.029$), while the insert type and depth of cut were not statistically significant at the 0.05 level.

Keywords: AISI 4340, Finish turning, Surface roughness, Taguchi method, Regression analysis, Variance analysis

Introduction

Machining is one of the most widely used manufacturing methods for producing engineering components that require controlled geometry, dimensional accuracy, and functional surface quality. Among machining operations, turning is particularly important for cylindrical components such as shafts, pins, sleeves, couplings, gears, and transmission elements. In finish turning, the final surface is affected by the combined influence of cutting speed, feed rate, depth of cut, tool geometry, tool material, workpiece hardness, and chip-formation conditions. Therefore, the selection of suitable cutting parameters is directly related to production efficiency, tool life, dimensional stability, and the service performance of the machined component.

Surface roughness is one of the most important indicators used to evaluate machining performance because it affects friction, wear, fatigue strength, sealing ability, contact stiffness, lubrication behaviour, and service life. In turning studies, the arithmetic average surface roughness value, R_a , is commonly used as a practical numerical response for comparing cutting conditions and developing prediction models. Surface roughness prediction and control have therefore been widely discussed in machining literature (Benardos & Vosniakos, 2003). From a theoretical point of view, feed rate is expected to have a strong influence on R_a because ideal roughness is closely related to feed rate and tool nose radius. However, the real surface generated during cutting can also be affected by built-up edge formation, vibration, tool wear, cutting temperature, coating behaviour, and workpiece material properties (Shaw, 2005; Trent & Wright, 2000). AISI 4340 is a nickel-chromium-molybdenum low-alloy steel widely used in demanding engineering applications due to its high strength, toughness, hardenability, fatigue

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resistance, and wear resistance. In engineering material selection, the relationship between material properties, service conditions, and manufacturing route should be evaluated together because the final performance of a component depends not only on the selected material but also on how that material is processed (Sahin, 2022). AISI 4340 is commonly preferred for critical components such as crankshafts, transmission shafts, gears, couplings, pins, fasteners, and aircraft landing-gear parts. However, the same properties that make AISI 4340 attractive for structural applications also make its machining more difficult by increasing cutting forces, cutting temperature, tool wear tendency, chip-control difficulty, and surface-integrity problems.

The study on AISI 4340 and comparable hard-turning applications show that surface roughness is generally controlled mainly by feed rate, while cutting speed, depth of cut, and tool condition may have secondary effects depending on the selected range. Lima et al. (2005) examined hard turning of AISI 4340 and reported that surface finish may improve with increasing cutting speed under low feed and depth-of-cut conditions, whereas increasing feed rate generally worsens surface quality. Suresh et al. (2012a) investigated hardened AISI 4340 steel using coated carbide inserts and related surface roughness and tool wear to selected cutting parameters. In another study, Suresh et al. (2012b) evaluated multilayer coated carbide tools and emphasized that low feed rate together with suitable cutting speed is important for obtaining better surface finish. Similarly, Sahoo and Sahoo (2012) compared uncoated and multilayer-coated carbide inserts in finish hard turning of AISI 4340 and evaluated surface roughness, chip morphology, cutting forces, and tool wear.

Tool material and coating condition are also important in finish turning of AISI 4340 steel. Uncoated carbide inserts are economical and widely available, but they may be more sensitive to wear and built-up edge formation under difficult cutting conditions. Coated carbide inserts can improve thermal resistance, reduce adhesion, and provide more stable cutting performance. For demanding hard-turning conditions and high surface-quality requirements, CBN and PCBN tools have also been investigated. More et al. (2006) compared coated carbide and PCBN inserts in turning hardened AISI 4340 steel, while Coelho et al. (2007) studied tool wear in turning hardened AISI 4340 with coated PCBN tools. Caydaş (2010) also reported that tool type affects surface roughness, tool wear, tool-chip interface temperature, and microhardness in machining AISI 4340.

The Taguchi method uses orthogonal arrays and signal-to-noise ratios to determine favourable factor levels with fewer experimental trials (Taguchi, 1990). Ross (1996) explained that Taguchi designs are especially useful for identifying robust factor levels in engineering applications, while Montgomery (2017) emphasized the role of ANOVA in interpreting the statistical significance of experimental factors. For surface roughness, the smaller-is-better quality characteristic is commonly selected because the objective is to minimize Ra. ANOVA is then used to determine the contribution and significance of each factor, while regression analysis can be used to develop an empirical equation for predicting Ra within the investigated parameter range.

Statistical optimization and modelling methods are useful for converting experimental machining results into practical process knowledge. In Taguchi-based studies, feed rate is consistently reported as the most influential factor for Ra, while cutting speed generally has a secondary effect and depth of cut is often the least influential factor within finish-turning ranges. For example, Aouici et al. (2012) reported a dominant feed-rate effect in hard-turning optimization, while Khmel et al. (2012) showed that feed rate remained the dominant parameter even when tool-related effects were included in the analysis. Meddour et al. (2015) also indicated that geometric and interaction effects can be observed in expanded Taguchi designs, but the feed-rate effect remains central to surface-roughness formation. These findings are consistent with the physical mechanism of feed marks and with the theoretical roughness relationship, $Ra \approx f^2/(32r_e)$, where f is feed rate and r_e is the tool nose radius. Nalbant et al. (2007), Özel and Karpaz (2005), and Rashid et al. (2016) demonstrated the usefulness of Taguchi, regression, and statistical modelling approaches in turning and hard-turning studies.

The hardness represents a practical transition region between conventional turning and hard turning. At this level, carbide and coated carbide inserts can still be used effectively, while CBN tools may provide improved surface finish but may not always be economically necessary for general finish-turning operations. For this reason, comparing uncoated carbide, CVD-coated carbide, and CBN inserts under the same experimental design is directly related to real production decisions. Instead of evaluating only cutting parameters, the present study also considers insert condition because the selected tool affects heat generation, friction at the tool-chip interface, edge stability, wear behaviour, and the final machined surface.

Based on this background, the present study focuses on finish turning of AISI 4340 steel under different cutting conditions. The study specifically examines the effects of cutting speed, feed rate, depth of cut, and insert types on the average surface roughness Ra. Three different insert conditions, namely uncoated carbide, CVD-coated carbide, and CBN, are considered to compare conventional and high-performance tool alternatives under the same

experimental structure. Therefore, a Taguchi L9 orthogonal array is used to determine favourable factor levels for minimum Ra, and regression analysis is performed to find out the relationship between Ra and the selected input parameters. In this way, the study moves from the general problem of surface-quality control in turning to the specific optimization of AISI 4340 finish turning using different insert conditions.

Materials and Method

Workpiece Material

The workpiece material was AISI 4340 steel with a measured hardness of approximately 32 HRC. Cylindrical specimens had an initial diameter of 50 mm and a total length of 180 mm. Before the experimental cuts, the external diameter was finish turned from 50 mm to 46 mm. For each experimental condition, an 8 mm long external cylindrical region was machined and used for surface-roughness measurement. Figure 1 shows the AISI 4340 workpiece specimen used in the experiments. The nominal chemical composition of AISI 4340 steel is given as follows (wt.%): (C = 0.38-0.43; Mn = 0.60-0.80; Si = 0.15-0.35; Cr = 0.70-0.90; Ni = 1.65-2.0; Mo = 0.20-0.30; P ≤ 0.035; S ≤ 0.040).



Figure 1. AISI 4340 workpiece specimens

Machine Tool and Inserts

External finish-turning experiments were conducted on a Spinner TC65 CNC turning centre, shown in Figure 2. Three insert conditions were evaluated: uncoated carbide, CVD-coated carbide, and CBN. All inserts belonged to the 09T308 dimensional group and had a constant nose radius of 0.8 mm. Keeping the nose radius constant reduced geometric variation and allowed the comparison to focus on insert condition. The insert types, insert codes, descriptions, and corresponding insert hardness values are given in Table 1.



Figure 2. Spinner TC65 CNC turning centre

Table 1. Selected cutting tools, coding and hardnesses of the cutting tools.

Tool Condition	Insert Code	Description	Insert Hardness (HV)
Uncoated carbide	CCGT09T308-LH BU810	Uncoated cemented carbide	1600
CVD-coated carbide	CCMT09T308-P3 6325	TiN/TiCN/Al ₂ O ₃ /TiN; P20-P30	2800
CBN	CCGW09T308 S02020-2S	Brazed CBN; CBN content 70-75%	3500

The HV values in Table 1 were used to numerically represent the cutting-insert condition in the Minitab regression and Taguchi analyses. These values should not be interpreted as isolated hardness-only effects because the inserts also differ in coating structure, substrate, thermal behaviour, wear resistance, edge preparation, and tool material class. The CBN insert has a chamfered and honed edge preparation, whereas the uncoated carbide and CVD-coated carbide inserts differ mainly in coating and substrate characteristics.

Experimental Design

A Taguchi L9 (3^4) orthogonal array was used to evaluate four experimental factors at three levels. The investigated factors were cutting speed (V_c), feed rate (f), depth of cut (a_p), and insert types represented by the HV. Table 2 lists the factors selected, factor levels and their units used in the experimental design while Table 3 illustrates the experimental planning in the machining of AISI 4340 steels using various cutting tools under different conditions as pointed out above.

Table 2. Experimental factors and their levels

Factor	Level 1	Level 2	Level 3	Unit
Cutting speed, V_c	90	160	230	m/min
Feed rate, f	0.08	0.15	0.22	mm/rev
Depth of cut, a_p	0.6	1.2	1.8	mm
Insert hardness, HV	1600	2800	3500	HV

Table 3. Experimental planning in the machining of AISI 4340 steels

Run	V_c (m/min)	F (mm/rev)	A_p (mm)	Hardness (HV)
1	90	0.08	0.6	1600
2	90	0.15	1.2	2800
3	90	0.22	1.8	3500
4	160	0.08	1.2	3500
5	160	0.15	1.8	1600
6	160	0.22	0.6	2800
7	230	0.08	1.8	2800
8	230	0.15	0.6	3500
9	230	0.22	1.2	1600

Surface-roughness Measurement



Figure 3. Fixed surface-roughness surface measurement system, and to be measured specimen

Surface roughness was measured using a Mitutoyo SJ-310 instrument on the 8 mm long machined region. The surface-roughness measurement system, and to be measured specimens is shown in Figure 3. The evaluation length was 5 mm. Two machining repetitions were performed for each experimental condition, and three roughness traces were obtained from each repetition. Thus, six Ra measurements were obtained for each experimental condition. A V-block fixture was used to keep the cylindrical specimens stable during measurement and to reduce possible measurement errors caused by specimen movement.

Statistical Analysis

Because the objective was to minimise Ra, the smaller-is-better signal-to-noise (S/N) quality characteristic was applied. Response tables were generated for means and S/N ratios. For the smaller-is-better criterion, the factor level with the highest S/N ratio indicates the favourable level. The S/N ratio was calculated using the following equation (1):

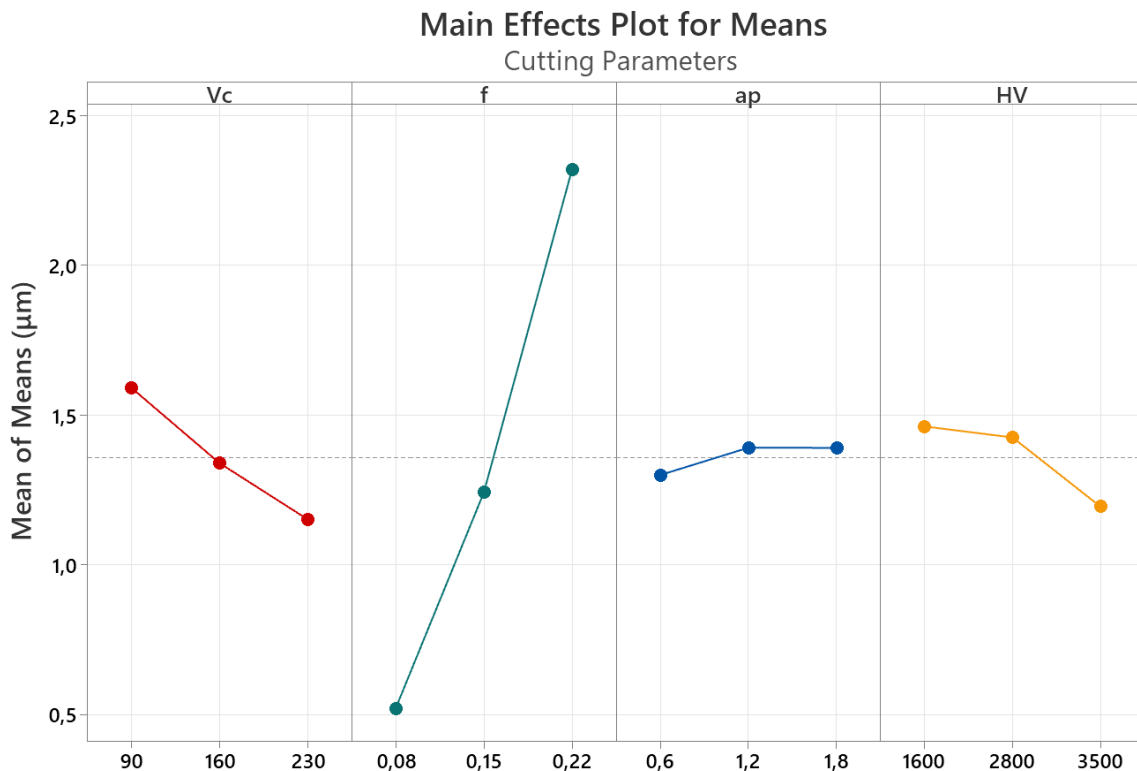
$$\frac{S}{N} = -10 \times \log_{10} \times \left[\frac{1}{n} \sum y_i^2 \right] \quad (1)$$

where n is the number of measurements and yi is the measured response.

Results and Discussion

Experimental Results

The main-effects plots for the mean Ra values and S/N ratios obtained from the Taguchi analysis are presented in Figure 4 (a, b), respectively. -Figure 4(a) shows the main-effects plot for the mean Ra values. The plot indicates that Ra increased strongly with increasing feed rate, whereas Ra decreased with increasing cutting speed. The mean Ra value also decreased as the insert hardness level increased from 1600 HV to 3500 HV. In contrast, depth of cut showed only a very small effect on Ra within the investigated range. Based on the mean response, the favourable factor levels were Vc level 3, f level 1, ap level 1, and HV level 3, corresponding to Vc = 230 m/min, f = 0.08 mm/rev, ap = 0.6 mm, and HV = 3500.



(a) Mean Ra values

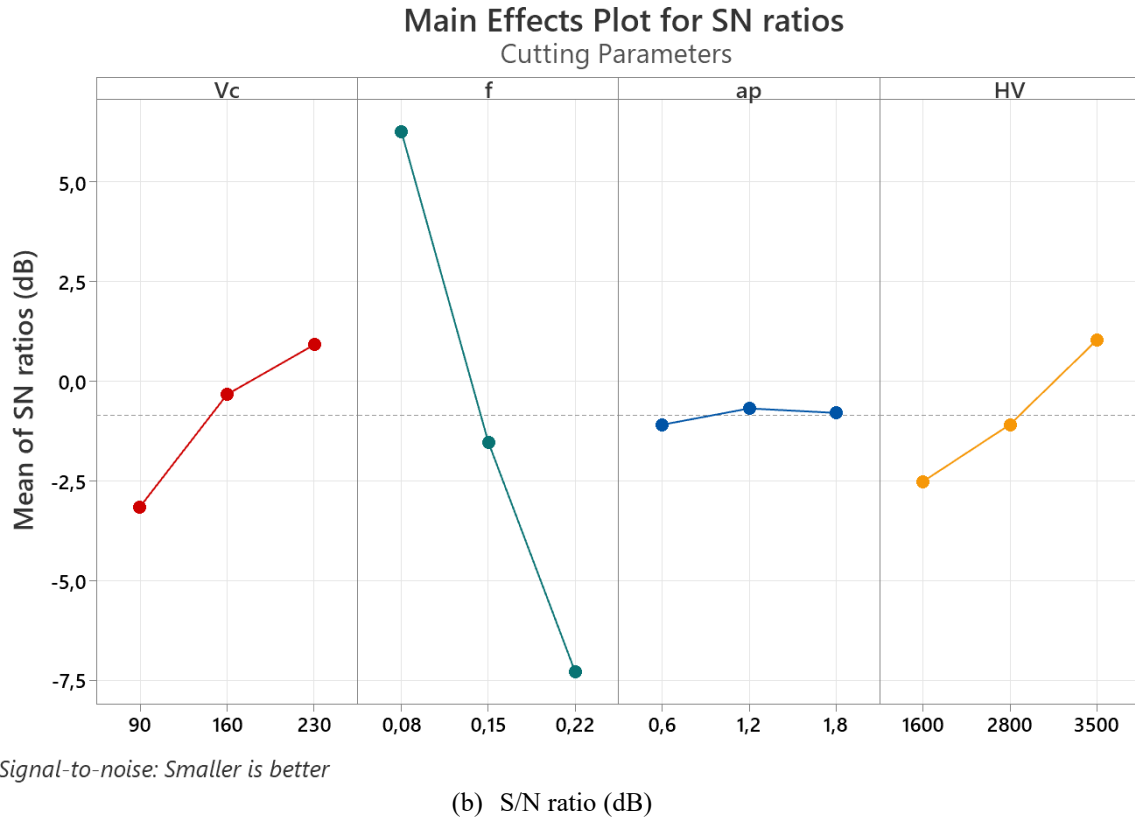


Figure 4. Main-effects plot for output like mean Ra and S/N ratios values

Figure 4 (b) shows the main-effects plot for the S/N ratios (dB). The steepest slope was obtained for feed rate, confirming that the feed rate was the most influential factor affecting on Ra, again. The cutting speed had the second effect and the HV indicates the third effect on the S/N response, but the depth of cut was no effective. These results demonstrated that surface roughness in finish turning of AISI 4340 steel was mainly controlled by feed rate, followed by cutting speed, while insert type and depth of cut has no considerable effective on the selected experimental ranges.

The experimental results indicated that the lowest feed rate generally produced the lower the Ra values, whereas, the trials performed with the highest feed rate generated the higher Ra values, which are consistent with the theoretical surface-generation mechanism in any cutting process, because increasing the feed rate leading to generated the feed marks on the machined surface. This is due to coming from theoretical back-ground of average surface roughness equation ($Ra = f^2 / (32 * r_c)$), where f = feed rate (mm/rev.), r_c = tool insert's radius (mm) that is equal to 0.8mm in present case. As results, the trial 4 gave the minimum measured Ra value among the conducted experiments. However, the optimum factor levels should be determined separately using the Taguchi S/N response analysis, which evaluates the average effect of each factor level across the experimental design.

These findings are generally consistent with previous studies on the turning and hard turning of AISI 4340 steel. Das et al. (2017) reported that feed was the most significant parameter affecting surface roughness, followed by cutting speed, while depth of cut had a comparatively lower and statistically insignificant effect. This agrees with the present ANOVA results, where feed rate had the highest contribution to Ra, cutting speed was the second most influential factor, and depth of cut had the lowest contribution. Similarly, Suresh et al. (2012a) reported that the combination of low feed rate, low depth of cut, and high cutting speed was beneficial for reducing surface roughness when machining hardened AISI 4340 steel with coated carbide inserts. Suresh et al. (2012b) also stated that low feed rate together with high cutting speed is necessary for minimizing surface roughness in hard turning of AISI 4340 steel using multilayer coated carbide tools. Therefore, the optimum Taguchi condition obtained in the present study, especially the low feed rate and high cutting speed levels, is compatible with these previous findings. The only difference is that the insert condition represented by HV showed a secondary and statistically insignificant effect in the present regression model. This can be attributed to the limited L9 experimental range and to the use of HV as a numerical representation of the overall insert condition rather than as an isolated hardness-only variable.

Taguchi Response Analysis

The Taguchi response analysis was performed using the smaller-is-better quality characteristic because the objective of this study was to minimise the average surface roughness, Ra. The response tables for the means and signal-to-noise ratios are presented in Table 4 and Table 5, respectively. In the response table for means, the factor level with the lowest mean value is considered favourable, whereas in the S/N response table based on the smaller-is-better criterion, the factor level with the highest S/N ratio is considered favourable.

Table 4. Response table for means (μm)

Level	Vc	f	ap	HV
1	1.5881	0.5186	1.2980	1.4602
2	1.3374	1.2395	1.3892	1.4233
3	1.1503	2.3177	1.3887	1.1923
Delta	0.4378	1.7992	0.0912	0.2678
Rank	2	1	4	3

As shown in Table 4, the lowest level averages were obtained at Vc level 3, f level 1, ap level 1 and HV level 3. These levels correspond to Vc = 230 m/min, f = 0.08 mm/rev, ap = 0.6 mm, and insert hardness = 3500 HV. Based on the delta values in Table 4, the factor ranking for the mean Ra values was determined as $f > Vc > \text{insert hardness (HV)} > ap$. This indicates that the feed rate had the strongest effect on the mean Ra value, while depth of cut had no effect within the investigated parameter range.

Table 5. Response table for S/N ratios: higher is better (dB)

Level	Vc	f	ap	HV
1	-3.1573	6.2477	-1.0958	-2.5197
2	-0.3366	-1.5339	-0.6878	-1.0909
3	0.9105	-7.2973	-0.7999	1.0271
Delta	4.0678	13.5450	0.4080	3.5467
Rank	2	1	4	3

As presented in Table 5, the S/N ratio results also confirmed the dominant influence of feed rate on Ra. Since the smaller-is-better criterion was used, higher S/N ratios indicate the better performance. According to Table 5, the highest S/N ratios (dB) were obtained at Vc level 3, f level 1, ap level 2, and insert hardness level 3. Therefore, the optimum factor levels predicted by the Taguchi S/N analysis were determined as Vc = 230 m/min, f = 0.08 mm/rev, ap = 1.2 mm, and insert hardness = 3500 HV. Based on the S/N delta values in Table 5, the factor ranking was $f > Vc > \text{insert hardness (HV)} > ap$. This result showed that feed rate was the most influential factor affecting Ra, followed by cutting speed and insert hardness, whereas depth of cut had the lowest influence. The favourable depth-of-cut level differed between the mean response and the S/N response. However, this difference should not be overemphasized because depth of cut had the lowest delta value in both response tables and the lowest contribution value in ANOVA.

Regression Analysis

Regression analysis was performed to develop a mathematical model for predicting the average surface roughness, Ra, as a function of cutting speed, feed rate, depth of cut, and insert hardness. In the model, cutting speed (Vc), feed rate (f), depth of cut (ap), and insert hardness (HV) were used as continuous input variables, while Ra was used as the response variable. The fitted multiple linear regression equation is given in equation (2).

$$Ra = 0.180 - 0.003127 Vc + 12.851 f + 0.076 ap - 0.0001290 HV \quad (2)$$

In Equation (2), Ra is expressed in micrometres, Vc is m/min, f is mm/rev, ap is mm, and HV is Vickers hardness. Table 6 reveals the regression coefficients for Ra output. The negative coefficient of Vc indicates that increasing cutting speed tended to reduce the Ra within the investigated parameter range. The positive coefficient of f shows that increasing feed rate increased the Ra. The positive coefficient of ap indicates a slight increasing tendency in the Ra with increasing depth of cut, whereas the negative coefficient of HV suggests that higher insert hardness tended to reduce the Ra. The R-squared value of 98.05% indicates that the regression model explains a large portion of the variation in Ra. The adjusted R-squared value of 96.10% also shows that the model has a strong explanatory capability after accounting for the number of predictors. These coefficients should be interpreted together with their p-values and the ANOVA results.

Table 6. Regression coefficients for Ra values.

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	0.180	0.309	0.58	0.591	-
Vc	-0.003127	0.000941	-3.32	0.029	1.00
f	12.851	0.941	13.65	< 0.001	1.00
ap	0.076	0.110	0.69	0.529	1.00
HV	-0.000129	0.000069	-1.88	0.133	1.00

As shown in Table 6, feed rate was statistically significant at the 0.05 significance level, with $p < 0.001$. This confirms that the feed rate had the strongest effect on Ra among the investigated factors. The cutting speed was also statistically significant, with a p-value of 0.029, indicating that increasing the cutting speed had a measurable decreasing effect on Ra in the experimental dataset. The insert condition represented by HV had a negative coefficient, indicating a decreasing tendency in Ra with increasing HV; however, its p-value of 0.133 shows that this effect was not statistically significant at the 0.05 level. Similarly, depth of cut was not statistically significant individually, with a p-value of 0.529. Therefore, the regression results support the Taguchi response analysis by showing that the feed rate was the dominant parameter affecting surface roughness, while cutting speed had a secondary statistically significant effect.

Analysis of Variance (ANOVA)

ANOVA was carried out to determine the effective factors in the machining of the steels at different conditions and the results are shown in Table 7. In this table, p-values are about 0.029, <0.001, 0.529, 0.133 for Vc, f, d, H, respectively. Smaller p-value signifies that the regression coefficient is highly significant at 95% confidence level, which supports the results of the regression. As presented in this table, SS, Seq SS and Contribution columns were also evaluated to determine how much of the total variation was explained for each factor. The regression model explained 98.05% of the total variation in Ra, while the error contribution was only 1.95%, indicating that the selected factors explained most of the variation in the experimental dataset. Among the individual factors, feed rate had by far the highest contribution with Seq SS = 4.85550 and Contribution = 90.73%. This result confirms that feed rate was the dominant parameter controlling Ra. The cutting speed had the second-highest contribution around 5.37%, and it was statistically significant at the 0.05 level ($p = 0.029$). The insert condition represented by HV had a lower contribution of 1.72% and was not statistically significant at the 0.05 level ($p = 0.133$). The depth of cut had the lowest contribution, with only 0.23%, and was not statistically significant ($p = 0.529$). Therefore, according to the ANOVA analysis, the influence ranking was $f > Vc > HV > ap$. This ranking is consistent with the Taguchi response tables and shows that depth of cut should not be interpreted as a dominant factor for Ra in this experimental range.

Table 7. Analysis of variance for mean Ra values.

Source	DF	Seq SS	Contrib.	Adj SS	Adj MS	F-Value	P-Value
Regression	4	5.24759	98.05%	5.24759	1.31190	50.35	0.001
Vc	1	0.28753	5.37%	0.28753	0.28753	11.03	0.029
f	1	4.85550	90.73%	4.85550	4.85550	186.34	< 0.001
ap	1	0.01233	0.23%	0.01233	0.01233	0.47	0.529
HV	1	0.09222	1.72%	0.09222	0.09222	3.54	0.133
Error	4	0.10423	1.95%	0.10423	0.02606	-	-
Total	8	5.35182	100.00%	-	-	-	-

The higher HV levels tended to reduce Ra within the investigated range. However, its p-value of 0.133 indicates that this effect was not statistically significant at the 5% level in the analysis. The HV values used in this study represent the cutting-insert condition numerically; they should not be interpreted as an isolated hardness-only effect because the inserts also differ in tool material class, coating structure, substrate, wear resistance, and edge preparation.

Figure 5 indicates the residual plots used to evaluate the adequacy of the regression model. The normal probability plot indicates that the residuals approximately follow a straight-line trend, suggesting that the normality assumption is reasonably satisfied. The residuals-versus-fitted-values plot does not show a clear systematic pattern, indicating that the residuals are randomly distributed around zero. The histogram of residuals also shows an approximately balanced distribution. The residuals-versus-order plot does not indicate a strong time- or order-related trend. Therefore, the residual plots in Figure 5 support the adequacy of the regression model for interpreting Ra within the investigated experimental range.

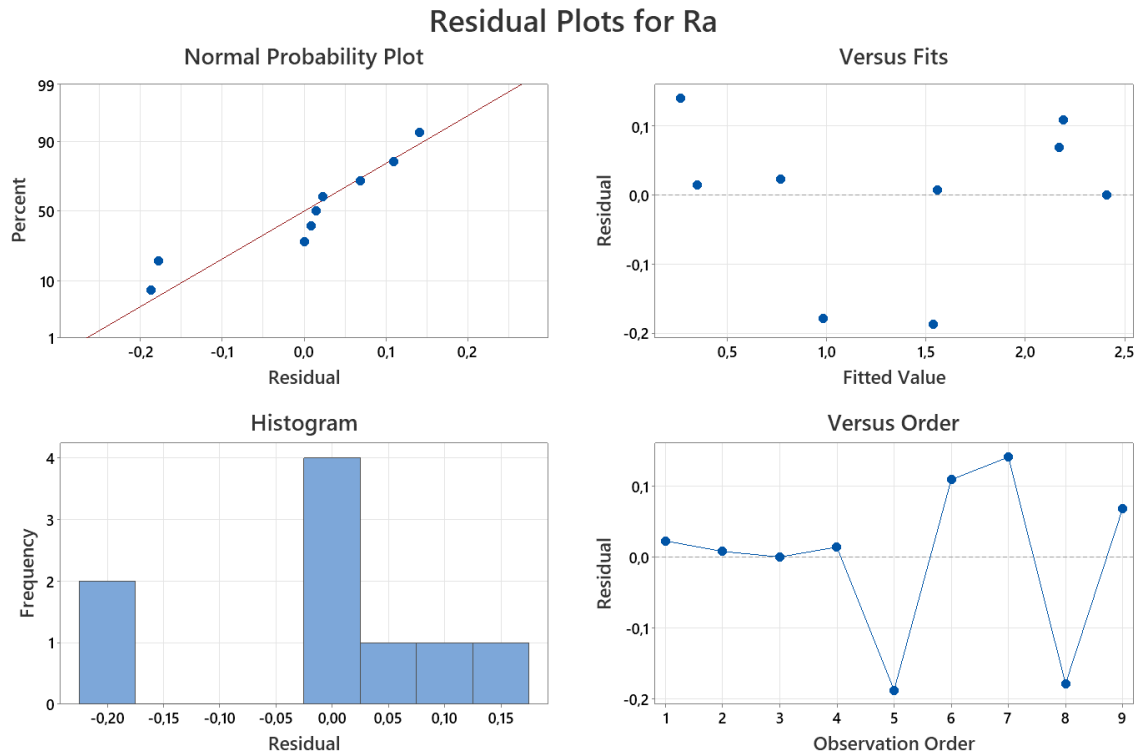


Figure 5. Residual plots for Ra regression model

Conclusion

This study investigated the effect of cutting speed, feed rate, depth of cut, and insert types on the average surface roughness, Ra, during the finish turning of AISI 4340 steel. For this purpose, a Taguchi L9 experimental design was used, and the experimental results were evaluated using Taguchi response analysis, regression analysis, ANOVA, and residual plots.

1. The measured Ra values ranged from 0.361 μm to 2.411 μm , showing that the investigated cutting parameters caused a clear variation in surface quality.
2. According to the Taguchi S/N response analysis, the optimum factor levels for minimising Ra were determined as $V_c = 230 \text{ m/min}$, $f = 0.08 \text{ mm/rev}$, $a_p = 1.2 \text{ mm}$, and insert hardness = 3500 HV, respectively.
3. Both the Taguchi response analysis and the regression results showed that feed rate was the dominant factor affecting Ra. In the variance analysis, feed rate was statistically significant at the 0.05 significance level with $p < 0.001$.
4. The regression model provided a strong explanation of the experimental data, with R-squared, adjusted R-squared, and predicted R-squared values of 98.05%, 96.10%, and 90.09%, respectively.
5. The ANOVA revealed that contribution factors also confirmed the strong effect of feed rate, which accounted for 90.73% of the total variation in Ra. Cutting speed was the second most influential factor according to contribution, with 5.37%, and it was statistically significant with a p-value of 0.029. Whereas, the insert type and the depth of cut did not show a statistically significant individual effect within the investigated experimental range.

Scientific Ethics Declaration

* The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the authors.

* This experimental machining study did not require ethics committee approval.

Conflict of Interest

* The authors declare that they have no conflicts of interest.

Funding

* The authors received no specific financial support for this study.

Acknowledgements or Notes

* This article was presented as an oral presentation at the International Conference on Research in Engineering, Technology and Science (www.icrets.net) held in Batumi/Georgia on July 09-12, 2026.

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To cite this article:

Aydemir, B., & Sahin, Y. (2026). Determination of the optimum cutting parameters on surface roughness in turning AISI 4340 steel. *The Eurasia Proceedings of Science, Technology, Engineering and Mathematics (EPSTEM)*, 41, 27-37.