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Taguchi-based optimization of CNC turning parameters to enhance surface finish of AISI 1045 steel

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Abstract

Surface roughness is a critical indicator of machining quality, directly affecting the functional performance and service life of manufactured components. This study aims to optimize the surface roughness of AISI 1045 steel by varying parameters (cutting speed, feed rate, and depth of cut) using Taguchi L9 orthogonal array. Experiments were conducted on a FANUC 0i-Mate CNC lathe using Al-TiN-coated VNMG inserts. Moreover, the surface roughness was measured in accordance with ISO standards. Analysis of Variance (ANOVA) revealed the depth of cut was the most influential factor (45.21%), followed by cutting speed and feed rate. The Signal-to-Noise (S/N) ratio was identified as optimal surface roughness of 0.323 μm (N5 grade) at the parameter, with a cutting speed of 240 mm/min, a feed rate of 0.2 mm/rev, and a depth of cut of 0.6 mm. The novelty of this study is the demonstration that Taguchi's design and ANOVA combined can achieve reliable optimization results with considerably reduced experimental effort and offer practical industrial deployment, including for Small and Medium-sized Enterprises (SMEs).

Keywords:

AISI 1045, cutting speed, depth of cut, feed rate, optimization.

1 Introduction

Surface roughness is a critical performance in precision machining processes that significantly affects the functional characteristics of the machined components, including fatigue strength, wear resistance, and dimensional precision [1][2][3]. In industries that demand high precision, such as aerospace, automotive, and tool manufacturing, superior surface quality is essential in meeting tight dimensional tolerances and minimizing secondary finishing processes [4]. Surface irregularities degrade mechanical performance and function as initial locations for defects such as micro-cracks and surface corrosion that can increase the risk of mechanical failure [5][6][7]. Among various materials, AISI 1045 medium-carbon steel is widely used due to its good mechanical strength and machinability [8]. This material is widely used in automotive and industrial machinery, especially in components that experience dynamic and rotational loads, including shafts, gears, and fasteners [9][10]

CNC turning is a widely used machining process for AISI 1045, and surface finish is affected by several machining parameters such as cutting speed, feed rate, and depth of cut [11][12]. Literature has shown that feed rate affects surface roughness; with a higher feed rate causing increased surface irregularities and accelerated tool

wear [12]. Conversely, lower cutting speed improves surface quality due to reduced cutting forces and better chip evacuation [13], [14]. The depth of cut also affects surface texture, where a greater depth will result in higher surface roughness due to the high mechanical loads at the tool-workpiece interface [15].

Inappropriate parameter selection in the CNC machining process can still cause a surface finish that is less than optimal. Optimizing machining parameters is essential for enhancing surface quality and efficiency, especially for AISI 1045 steel machining.

The study by Kashkool [5] and Rifelino [15] using the Taguchi method on the AISI 1045 CNC machining process obtained an RA value above 0.4 μm , while the Abbas [16] study using a full factorial design obtained a Ra value of 0.392 μm . In this study, the target surface roughness was set below 0.35 μm , which corresponds to the N5 super-finishing grade according to ISO surface texture classification, and is a common requirement for precision automotive shaft components and rotating AISI 1045 mechanical parts where enhanced fatigue and wear resistance are critical. The novelty of this study lies in providing an industry-feasible machining guideline that enables small and medium-sized industries to achieve N5-grade super-finishing surface quality (<0.35 μm) using low-cost Taguchi L9 optimization, standard CNC turning machines, and commercially available VNMG Al-TiN inserts—without requiring advanced optimization algorithms or high-end computational tools.

While extensive studies have investigated the influence of turning parameters on surface roughness for AISI 1045, many rely on multi-objective or hybrid optimization approaches such as Genetic Algorithms (GA), Response Surface Methodology (RSM), or Artificial Neural Networks (ANN). While this method is powerful, it still requires advanced computing resources and various software integrations, which are impractical for Small and Medium-sized Enterprises (SMEs). Furthermore, prior research frequently focuses on individual parameter effects but lacks a statistically rigorous, comparative evaluation using Signal-to-Noise (S/N) ratio analysis and Analysis of Variance (ANOVA) within a minimal-experiment framework. Therefore, the objective of this study is to optimize the CNC turning parameters—cutting speed, feed rate, and depth of cut—for AISI 1045 steel using the Taguchi method, to minimize surface roughness (Ra). The approach also incorporates S/N ratio analysis and ANOVA to ensure statistical reliability and process robustness.

2 Methods and materials

In this study, three important machining parameters—cutting speed, feed rate, and depth of cut—are varied experimentally to examine and optimize surface roughness in the CNC turning of AISI 1045 steel. The independent variables are 0.2, 0.4, and 0.6 mm of depth of cut, feed rate (0.1, 0.15, and 0.2 mm/rev), and cutting speed (150, 200, and 240 m/min). The parameter levels were selected based on the recommended cutting conditions from the Mitsubishi VNMG insert catalogue for machining medium carbon steel (AISI 1045). These parameter windows (cutting speed 150–240 m/min, feed rate 0.1–0.2 mm/rev, and depth of cut 0.2–0.6 mm) represent the typical industrial operating range used in CNC turning applications, especially in SMEs utilizing commercially available carbide inserts and standard CNC machines. A water-soluble coolant with a concentration ratio of 1:20 as a controlled variable. Data were analyzed using the Taguchi method and statistical techniques, including S/N ratio analysis and ANOVA.

The machining trials were conducted using a FANUC Series 0i-Mate-TD CNC turning machine, as depicted in Fig. 1. A VNMG 040416 carbide insert, coated with a composite layer of aluminum and titanium nitride (Al, TiN), was employed as the cutting tool, with its geometry and specifications detailed in Fig. 2. In this experiment, nine carbide inserts were used, with one new insert allocated for each of the nine experimental runs to eliminate the effect of cutting tool wear between trials. A schematic illustration of the surface roughness measurement setup and procedure is

presented in Fig. 3 to provide visual clarity of the measurement process. All experiments were performed under typical room temperature conditions (~25 °C) without active environmental control. However, all trials kept environmental factors consistent to ensure measurement reliability. The work-piece dimensions are presented in Fig. 4. CNC tool paths were programmed and simulated using Mastercam software to ensure consistency and accuracy during machining. Tables 1 and 2 show the chemical content and properties of the AISI 1045 material used in this study.

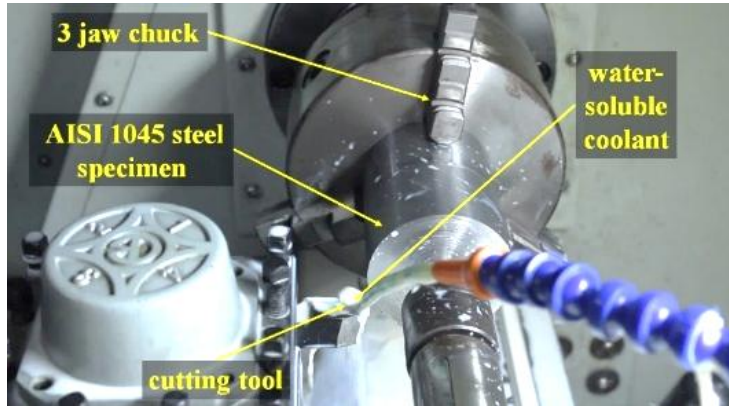


Fig. 1. Experiment setup.

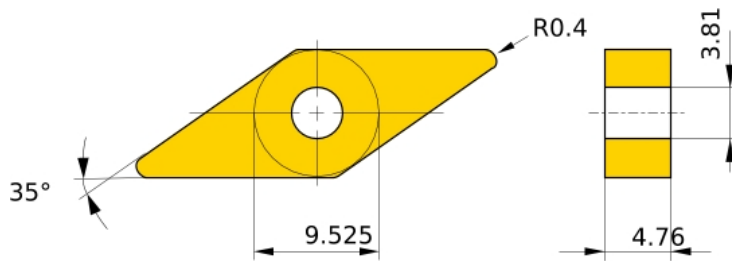


Fig. 2. Insert VNMG dimension [17].



Fig. 3. Surface roughness measurement setup using the Mitutoyo SJ-301 tester.

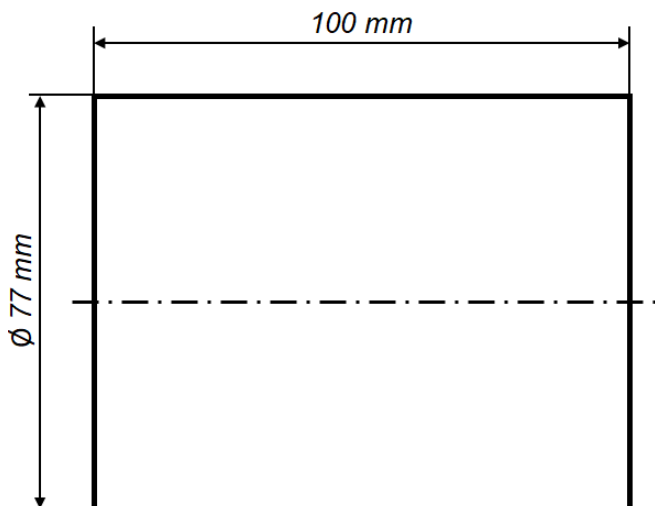


Fig. 4. Dimension of the specimen.

Table 1. Chemical composition of AISI 1045 [18].

Element	C	Fe	Mn	P	S
Percentage %	0.45	98.75	0.65	0.03	0.04

Table 2. Physical and mechanical properties of AISI 1045 steel [19]

Property	Value
Density (g/cm ³)	7.85
Hardness, Vickers (HV)	196
Tensile strength, ultimate (MPa)	655
Tensile strength, yield (MPa)	515
Elongation at break (%)	15
Modulus of elasticity (GPa)	206
Poisson's ratio	0.29

2.1 Design of experiments

The experimental design was structured using the Taguchi method, employing an L9 orthogonal array to investigate three parameters at three levels. The parameter levels are outlined in Table 3, while the orthogonal matrix is presented in Table 4. The Taguchi L9 orthogonal array was chosen for this study because it efficiently accommodates three factors at three levels, allowing for a systematic and balanced experimental design with only nine experiments compared to 27 experiments in a full factorial design. This OA significantly reduces time, cost, and resource consumption, which are valuable for small-scale machining industries with limited capacity or experimental capabilities. Several studies of CNC machining use Taguchi L9 orthogonal arrays for experiments involving three control factors; each at three discrete levels, using nine runs [20], [21], [22]. This approach provides full orthogonality and allows efficient estimation of main effects without interaction terms, significantly reducing the cost and time of the experiment compared to a full factorial design (27 runs). Surface roughness (Ra) was chosen as the response variable for analysis. The quality characteristic, surface roughness (Ra), was evaluated using the "smaller-the-better" criterion, with the S/N ratio computed as Eq. (1), where y_i represents the surface roughness in the i -th trial, n is the number of replications.

$$SN = -10 \log_{10} \left(\frac{1}{n} \sum_{i=1}^n y_i^2 \right) \quad (1)$$

Table 3. Parameter levels

Cutting parameter	Factor	Level		
		1	2	3
Cutting Speed, "CS" (m/min)	A	150	200	240
Feed rate "F" (mm/rev)	B	0.1	0.15	0.2
Depth of Cut "DoC" (mm)	C	0.2	0.4	0.6

Table 4. The Taguchi L9 (3³) orthogonal array

Experiment number	Cutting speed	Feed rate	Depth of cut
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

ANOVA was employed to identify significant factors affecting surface roughness. The Total Sum of Squares (SST) is calculated as Eq. (2)-Eq. (4), where (N) is the total data replication, (y_i) data on the first replication, (CF) correction factor, (T) the total data of all replications.

$$SST = \sum_{i=1}^N (y_i)^2 - CF \quad (2)$$

$$CF = \frac{T^2}{N} \quad (3)$$

$$T = \sum y_i \quad (4)$$

The sum of squares of the factors (SS_j) as Eq. (5)-Eq. (6), where, (SS_j) is the square of the j -factor.

$$SS_j = \sum_{i=1}^L \frac{T_i^2}{n_i} - CF \quad (5)$$

$$SS_e = SST - \sum SS_j \quad (6)$$

Then calculate the degrees of freedom of the factor (DF_j) as Eq. (7)-Eq. (9), where (MS_j) is the mean square of the j -th factor, (SS_j) is the square of the j -th factor, total degrees of freedom (DF_e), (F -value), mean square of error (MS_e).

$$DF_j = L - 1, DF_e = N - \sum DF_j \quad (7)$$

$$MS_j = \frac{SS_j}{DF_j}, MS_e = \frac{SS_e}{DF_e} \quad (8)$$

$$F_j = \frac{MS_j}{MS_e} \quad (9)$$

The percentage contribution of each factor was determined as Eq. (10).

$$\rho_j = \frac{SS_j}{SST} \times 100\% \quad (10)$$

2.2 Confirmation test

The best level results of the input process variables can be estimated by predicting optimal conditions with Eq. (11)-Eq. (12), where (\mathbf{p}) factors and optimal levels that affect quality characteristics, (η) the average value of data across all replications, (η_{opt}) the average value for factors and optimal levels, (n_t) the total number of trials, (η_i) data on the i -th replication.

$$N = \eta + \sum_{i=1}^p (\eta_{opt} - \eta) \quad (11)$$

$$\eta = 1/n_t \sum_{i=1}^{n_t} \eta_i \quad (12)$$

Then calculate the prediction interval for optimal conditions as Eq. (13)-Eq. (14), where ($F_{\alpha,1,DF_e}$) is the F-ratio at $\alpha\%$ significance level (this data is taken from the F0.05 distribution table), (DF_e) is the degrees of freedom of error, (ve) is the mean square of error, ($neff$) is the number of effective values, (r) is the total number of confirmation tests, (n) is the total number of tests, (Vt) is the number of degrees of freedom of the most influential factor.

$$Cl = \pm \sqrt{F_{\alpha,1,DF_e} \times Ve \times \left(\frac{1}{neff} + \frac{1}{r} \right)} \quad (13)$$

$$neff = \frac{n}{1 + Vt} \quad (14)$$

2.3 Measurement repeatability and surface roughness evaluation

To ensure repeatability and reliability, each surface roughness measurement was conducted three times at equidistant points along the machined surface under consistent environmental and

operational conditions. The average value of the three readings (Ra_1, Ra_2, Ra_3) was used as the representative surface roughness (Ra) value for each experimental run. This triplicate measurement approach is aligned with best practices in surface metrology and conforms to ISO 4287 and ISO 4288 standards for evaluating surface texture.

Using three repeated measurements reduces the impact of local irregularities or outliers, improves statistical robustness, and enables a more accurate estimation of process variability. The Coefficient of Variation (CV) was monitored to verify that dispersion among the three readings remained within acceptable metrological limits (typically $<10\%$).

A Mitutoyo SJ-301 portable surface roughness tester, which conforms with DIN EN ISO 4288:1996, ISO 4287:1997, and JIS B0601:2001 standards, was used to measure surface roughness. Before use, the device was calibrated using a certified calibration specimen from Mitutoyo ($Ra = 0.8 \mu\text{m} \pm 0.02 \mu\text{m}$). The calibration procedure is zero setting, stylus check, and repeatability verification through several measurements of reference surfaces. The standardization measurement conditions are: (1) limit length: 0.8 mm (λc); (2) evaluation length: 4.0 mm (5 limits); (3) stylus tip radius: 5 μm ; and (4) measurement speed: 0.5 mm/s. The settings ensure that the surface roughness characterization is consistent on each specimen, with high repeatability and compliance with international metrology standards.

3 Results and discussion

Although the Taguchi method provided a practical and cost-effective framework for optimizing machining parameters, several limitations exist in this study. First, using an L9 orthogonal array restricts the resolution of potential interaction effects between process parameters. Second, only three input variables (cutting speed, feed rate, and depth of cut) were considered, while other influential factors—such as tool nose radius, coolant flow rate, or tool wear progression—were held constant or excluded. Third, the surface roughness was measured as the sole performance indicator without considering Material Removal Rate (MRR), tool wear, or energy consumption, which is critical for holistic process optimization.

However, it is important to note that the Taguchi method generates optimal settings only within the pre-selected parameter window used in the design of the experiment. Therefore, the recommended machining parameters in this study should be interpreted as practical guidelines under realistic industrial operating ranges, rather than a universal global optimum outside the specified tested levels.

In addition, the confirmation test was limited to a single run, which may not fully account for process variability across different batches or machines. Environmental factors such as temperature, machine vibration, or tool chatter were also not monitored. Future work may incorporate a larger experimental design (e.g., L27 or RSM), include more process variables, or apply multi-objective optimization techniques such as NSGA-III. Integrating machine learning models with real-time sensor data could also enhance predictive accuracy and robustness in industrial settings.

Future investigations are encouraged to incorporate MRR as an additional response variable alongside surface roughness, to establish a more comprehensive decision framework that simultaneously evaluates machining productivity and surface quality. Integrating MRR with Taguchi-based optimization could provide a more balanced trade-off perspective and further enhance industrial relevance, particularly for SMIs targeting both efficiency and precision in machining operations.

The results of CNC turning machining are shown in Fig. 5, along with the sequence of experiments according to the settings in Table 4. Surface roughness data is presented in Table 5 with surface roughness (Ra) values ranged from 0.33 μm to 2.13 μm . In the first experiment, the Ra value was 2.13 μm ; in the ninth experiment, it was the lowest at 0.33 μm .



Fig. 5. Results of CNC turning experiments showing surface characteristics.

The S/N ratio was employed to identify the optimum factors and levels. Table 5 shows the S/N ratio values of surface quality from each factor. Fig. 6 shows the factors and levels that affect surface quality. For cutting speed, 240 m/min gives a higher influence than 150 m/min and 200 m/min. It can be said in this study that the greater the cutting speed, the greater the influence on surface quality. A feed rate of 0.2 mm/rev also gives a higher influence than 0.1 mm/rev and 0.15 mm/rev. Depth of cut 0.6 also gives a more decisive influence than 0.2 mm and 0.4 mm. According to these results, the optimal combination is achieved at CS 240 m/min, F 0.2 mm/rev, and DoC 0.6 mm.

Table 5. Surface roughness test data

Factors			Surface roughness (μm)				S/N (db)
Cutting speed	Feed rate	Depth of cut	Ra_1	Ra_2	Ra_3	ΣRa	
1	1	1	0.2	2.11	2.32	2.13	-6.588
1	2	2	0.4	1.32	1.4	1.36	-2.673
1	3	3	0.6	0.5	0.34	0.41	7.565
2	1	2	0.4	0.88	0.86	0.89	0.973
2	2	3	0.6	0.29	0.31	0.29	10.738
2	3	1	0.2	0.61	0.78	0.74	2.546
3	1	3	0.6	0.3	0.25	0.25	11.927
3	2	1	0.2	0.6	1.27	1.05	-0.836
3	3	2	0.4	0.35	0.33	0.33	9.536

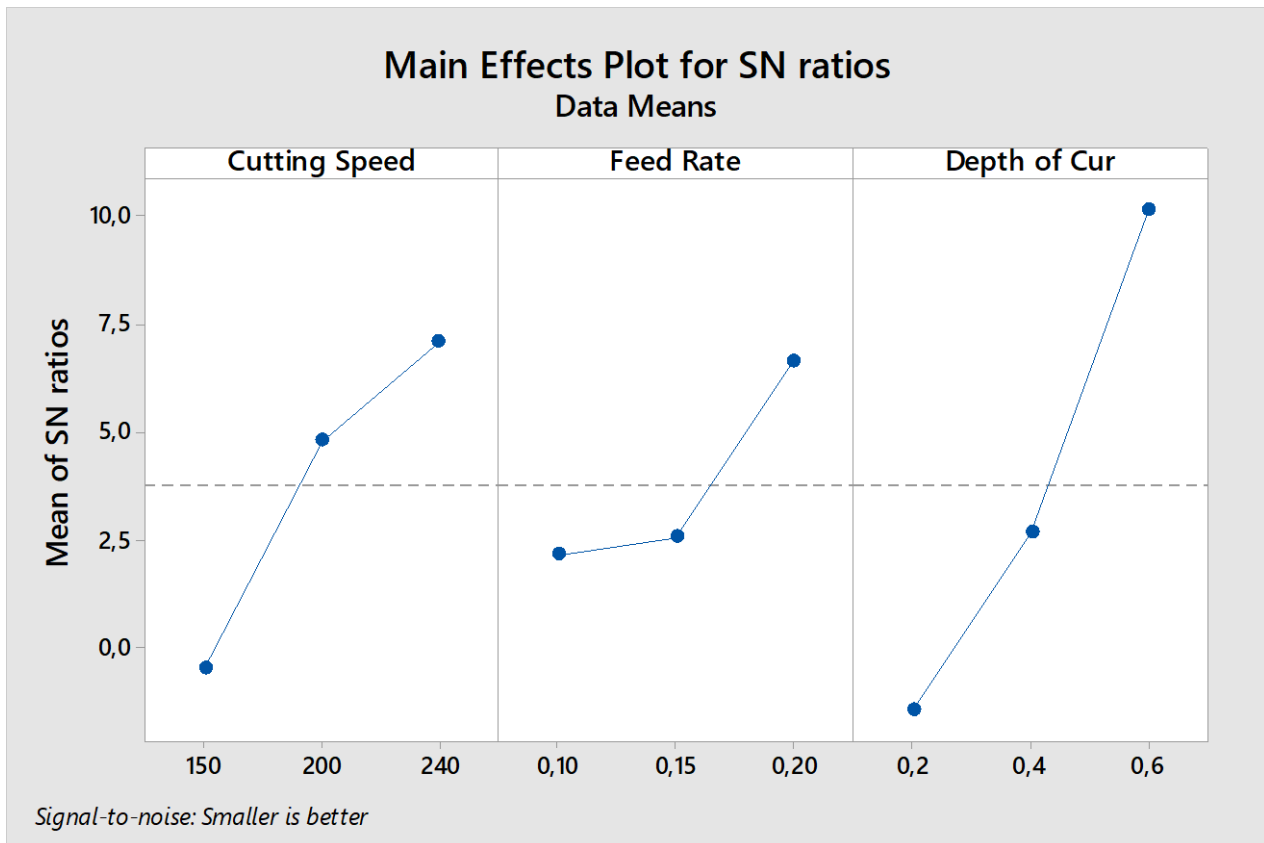


Fig. 6. Signal to noise surface roughness graph.

Table 6 presents the S/N ratio values calculated for each level of the machining parameters—cutting speed, feed rate, and depth of cut—using the "smaller-the-better" criterion, as surface roughness (Ra) is to be minimized. The delta value indicates the difference between the highest and lowest points. The S/N ratio of each factor indicates the influence of that factor on surface finish quality.

Table 6. Signal-to-noise ratio for surface roughness response

Level	Cutting speed	Feed rate	Depth of cut
1	-0.4980	2.1619	-1.4587
2	4.7932	2.5525	2.6570
3	7.0824	6.6631	10.1792
Delta	7.5804	4.5012	11.6379
Rank	2	3	1

From the S/N analysis, depth of cut shows the highest delta (11.6379), followed by cutting speed (7.5804), and then feed rate (4.5012). This ranking indicates that the depth of cut is the most significant factor influencing surface roughness, whereas the feed rate has the least impact. Specifically, the optimal surface finish was obtained at a depth of cut of 0.6 mm, a cutting speed of 240 m/min, and a feed rate of 0.2 mm/rev—all of which correspond to the levels with the highest S/N ratio, thus minimizing surface roughness.

The significant influence of the depth of cut may be attributed to its impact on cutting force and plastic deformation at the tool-work-piece interface. Higher depth of cut increases the engagement of the cutting tool, which can enhance the chip formation process and result in a smoother surface when the process is stable. The

improvement in surface finish from higher cutting speeds is most likely due to better chip evacuation and reduced Built-Up Edge (BUE) formation, as supported by Mohammad et al. [13]. The effect of relatively smaller feed rates is relevant to the research of Lubis et al. [8], where feed rates above 0.2 mm/rev cause vibration and increase surface roughness. In general, the S/N ratio analysis confirmed that the combination of high cutting speed, low feed rate, and high depth of cut resulted in the optimal (lowest) surface roughness. This finding supports the effectiveness of the Taguchi method in obtaining optimal machining process parameters for CNC turning of AISI 1045 steel. The optimal surface roughness achieved in this study was 0.323 μm using a cutting speed of 240 m/min, a feed rate of 0.2 mm/rev, and a depth of cut of 0.6 mm, corresponding to an N5 super-finishing grade. This result is favorable compared to previous studies on AISI 1045 steel.

For example, Kashkool [5] reported a minimum Ra of 0.411 μm under similar machining conditions using TiN-coated carbide inserts, while Rifelino et al. [15] achieved a Ra of 0.437 μm using an L9 Taguchi approach without any surface coating. Another recent study by Abbas et al. [19] demonstrated a surface roughness of 0.392 μm under dry cutting conditions using edge-modified carbide tools. These comparisons indicate that the parameter combination used in the present work and applying Al-TiN-coated inserts, produced a superior surface finish. This performance can be attributed to improved chip evacuation and reduced friction at the tool-work-piece interface, confirming the effectiveness of the selected cutting conditions and the robustness of the Taguchi optimization framework.

ANOVA was employed to evaluate the significance of each machining parameter on surface roughness. Table 7 presents the

Table 7. Analysis of variance

Factors	DF	SS	Contribution (Rho %)	MS	F-value	P-value
Cutting speed	2	1.01749	32.98	0.508	28.62	0.034
Feed	2	0.55749	18.07	0.278	15.68	0.060
Depth of cut	2	1.47482	47.80	0.737	41.48	0.024
Error	2	0.03556	1.15	0.017		
Total	8	3.08536	100			

Table 8 shows the predicted surface roughness value at optimal conditions of 0.451 μm with an interval of $\pm 0.604 \mu\text{m}$. A confirmation experiment was carried out using the best parameters, and the surface roughness was assessed at three distinct locations to obtain more precise results. The optimal surface roughness value of 0.323 μm was confirmed through experimental validation (confirmation test) using the optimal parameters predicted by the Taguchi L9 method.

Table 8. Predicted surface roughness values and intervals

Prediction (μm)	Interval (μm)
0.451	± 0.604

The result of the confirmation experiment of 0.323 μm was shown in Table 9 within the predicted value range, with a value of $0.451 \pm 0.604 \mu\text{m}$, where the results validate the effectiveness of

Table 9. Results of confirmation experiment

Factors			Surface roughness (μm)				S/N (db)
Cutting speed	Feed rate	Depth of cut	Ra_1	Ra_2	Ra_3	ΣRa	
3	3	3	0.35	0.30	0.32	0.323	9.801

Based on the comparison of results on Table 10, this study shows the lowest surface roughness (Ra) result of 0.323 μm compared to previous studies, although using the same feed rate value as the Rifelino study [15] and higher than Kashkool [5] and Abbas [16]. This shows that selecting Al-TiN-coated VNMG inserts and combining the Taguchi L9 optimization method with

results of the variance analysis, highlighting the contribution and statistical relevance of cutting speed, feed rate, and depth of cut. The significance of each factor was assessed using the F-test by comparing the computed F-value against the critical value from the F-distribution table. In this study, the threshold F-table value was 5.41 at a 95% confidence level. A factor is considered statistically significant if its F-value is greater than or equal to 5.41; otherwise, it is deemed insignificant. Based on the results, all three factors—cutting speed ($F = 28.62$), feed rate ($F = 15.68$), and depth of cut ($F = 41.48$)—exceeded the critical threshold, indicating that they significantly affect surface roughness.

The significance of the influence of each factor on surface roughness is shown in the P-value column in this study using a significance value (α) = 5%. If the P-value ≤ 0.05 , then the factor significantly influences surface roughness; if the P-value ≥ 0.05 , then the factor does not have a significant influence. The depth of cut and cutting speed factors significantly influence surface roughness with a P-value of cutting speed = $0.034 \leq 0.05$ and a P-value of the depth of cut = $0.024 \leq 0.05$. In contrast, the feed rate factor does not significantly influence this study, with a P-value of feed rate = $0.060 \geq 0.05$.

Based on the percentage of contributions from the highest to the lowest value, the depth of cut factor has the most significant contribution in the first position of 45.21%, followed by cutting speed of 30.96% and feed rate of 16.68% to surface roughness. Depth of cut had the most dominant influence (45.21%) on surface roughness, likely due to increased material removal per pass which intensifies cutting forces and surface deformation at the tool-workpiece interface.

the Taguchi experiment. According to ISO standards, the confirmation experiment result falls within the super-finishing category. These findings are particularly beneficial for Small and Medium-sized Industries (SMIs) that lack advanced multi-objective optimization tools and are limited by cost, technical skills, or software availability. The Taguchi L9 design in this study demonstrates that optimal surface finish can be achieved with minimal experimentation, low-cost tools, and standard CNC equipment. Through the identified optimal parameter settings—a cutting speed of 240 m/min, a feed rate of 0.2 mm/rev, and a depth of cut of 0.6 mm—SMIs can achieve super-finishing surface quality (grade N5) without the need for sophisticated systems or excessive trial and error. This finding reinforces the practical value of the Taguchi method in real-world machining environments, particularly for SMIs in the automotive or mechanical component manufacturing sectors.

ANOVA can improve cutting performance. Al-TiN-coated inserts have higher wear resistance and lubrication ability, which contribute to smoother surfaces. In addition, a higher cutting speed (240 m/min) also plays a role in improving surface quality during the CNC turning process. The Taguchi L9 orthogonal array combined with ANOVA allowed us to locate an operational region

that produced low surface roughness while requiring only nine experimental runs. This shows the method's practical efficiency for preliminary optimization in lab and small-scale industrial settings. However, because different experimental designs (for example L27

or a full factorial) provide higher resolution for interactions and may find alternative optima, a direct comparative study is needed before claiming unequivocal superiority in surface quality.

Table 10. Comparison of results

Author	Method	Insert type	Cutting speed (m/min)	Feed rate (mm/rev)	DoC (mm)	Ra (μm)
This study	Taguchi L9 + ANOVA	VNMG + Al-TiN	240	0.2	0.6	0.323
Kashkool [5]	Taguchi L27	TiN	180	0.15	0.5	0.411
Abbas [16]	Full factorial	Uncoated carbide	220	0.18	0.4	0.392
Rifelino [15]	Taguchi L9	Standard carbide	200	0.2	0.5	0.437

4 Conclusions

This study investigated the optimization of machining parameters in CNC turning of AISI 1045 steel using the Taguchi method with an L9 orthogonal array. The surface roughness Ra was selected as the key response variable, and three parameters, namely cutting speed, feed rate, and depth of cut, were each one evaluated at three levels. The findings showed that a cutting speed of 240 m/min, a feed rate of 0.20 mm/rev, and a depth of cut of 0.6 mm produced the lowest Ra value (0.323 μm) and were the best parameters for reducing the surface roughness of AISI 1045. The most significant factor based on ANOVA analysis was the depth of cut (47.80%), cutting speed (32.98%), and feed rate (18.07%). These findings confirm the ability of the Taguchi method to optimize machining settings with minimal trial and error. Furthermore, these findings demonstrate that proper parameter selection can significantly improve surface finish on AISI 1045 steel. This optimization is helpful in precision manufacturing applications to achieve good surface quality. A smooth surface quality of AISI 1045 steel in this study can be achieved using readily available equipment and minimal testing.

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