

## Investigating the Dominance of Depth of Cut on Surface Integrity in Al-Mg3 Turning with Large-Nose-Radius Tools

Ali Ahmed Ali Musbah<sup>1\*</sup>, Gaith Ibraheem Abdulhadi<sup>2</sup>

<sup>1</sup> General Department, Faculty of engineering, Bani Waleed University, Bani Waleed, Libya

<sup>2</sup> Mechanical Engineering Department, Faculty of Engineering, Bani Waleed University, Bani Waleed, Libya

\*Corresponding author: [alimusbah.aa@gmail.com](mailto:alimusbah.aa@gmail.com)

### دراسة هيمنة عمق القطع على سلامة السطح في خراطة سبيكة الألومنيوم-المغنيسيوم (Al-Mg3) باستخدام أدوات ذات نصف قطر أنف كبير

علي أحمد علي مصباح<sup>1\*</sup>، غيث إبراهيم عبد الهادي<sup>2</sup>

<sup>1</sup> القسم العام، كلية الهندسة، جامعة بني وليد، بني وليد، ليبيا

<sup>2</sup> قسم الهندسة الميكانيكية، كلية الهندسة، جامعة بني وليد، بني وليد، ليبيا

Received: 26-12-2025; Accepted: 09-03-2026; Published: 24-03-2026

#### Abstract

This study presents a systematic investigation into the parametric optimization of surface roughness during computer numerical control (CNC) turning of aluminum-magnesium alloy (Al-3Mg), utilizing cutting inserts with a fixed nose radius of 1.2 mm. Recognizing the critical role of surface quality in advanced engineering applications, this research employs a robust experimental strategy grounded in the Taguchi philosophy. A triadic framework of control factors—cutting speed, feed rate, and depth of cut—was established, each examined across three distinct levels within an L9 orthogonal array to ensure statistical efficiency and analytical rigor. The methodological approach integrates Signal-to-Noise (S/N) ratio analysis with comprehensive Analysis of Variance (ANOVA) to delineate the optimal cutting regime and quantitatively apportion the contribution of each parameter to surface roughness. The findings reveal a distinct hierarchy of influence: depth of cut emerges as the dominant factor, accounting for a substantial 60.71% of the variance in surface roughness, closely followed by cutting speed with a significant contribution of 36.12%. In contrast, feed rate exhibits a marginal influence, contributing only 2.79% under the investigated conditions. The optimized parametric combination—achieved at a feed rate of 0.5 mm/rev, a cutting speed of 500 rpm, and a depth of cut of 0.5 mm—demonstrates a synergistic balance that minimizes surface irregularities. These insights offer a compelling contribution to precision manufacturing, providing a data-driven framework for enhancing surface integrity in the machining of light alloys while minimizing experimental overhead.

**Keywords:** CNC turning, Al-3Mg alloy, surface roughness, Taguchi method, ANOVA, parametric optimization, surface integrity.

#### المخلص

تقدم هذه الدراسة بحثاً منهجياً في التحسين البارامترية لخشونة السطح أثناء عمليات الخراطة باستخدام الحاسوب الرقمي (CNC) لسبيكة الألومنيوم-المغنيسيوم (Al-3Mg)، بالاعتماد على قواطع قطع بنصف قطر ثابت يبلغ 1.2 مم. وإدراكاً للدور المحوري لجودة السطح في التطبيقات الهندسية المتقدمة، يعتمد هذا البحث استراتيجية تجريبية متينة قائمة على منهجية تاغوتشي. وقد تم وضع إطار ثلاثي من العوامل المتحكم فيها وهي سرعة القطع، ومعدل التغذية، وعمق القطع ودراسة كل منها عبر ثلاثة مستويات متميزة ضمن مصفوفة متعامدة من النوع L9، وذلك لضمان الكفاءة الإحصائية والدقة التحليلية. يتكامل النهج المنهجي المستخدم في تحليل نسبة الإشارة إلى الضوضاء (S/N) مع تحليل التباين (ANOVA) الشامل لتحديد الظروف المثلى للقطع، وتوزيع مساهمة كل عامل في خشونة السطح كميًا. تكشف النتائج عن تسلسل هرمي واضح للتأثير، إذ يبرز عمق القطع كأكثر العوامل تأثيراً، حيث يساهم بنسبة 60.71% من التباين الكلي في خشونة السطح، تليه سرعة القطع بمساهمة معنوية بلغت 36.12%. في المقابل، يُظهر معدل التغذية تأثيراً هامشياً لا يتجاوز 2.79% في الظروف المدروسة. تمثلت التركيبة المثلى للمعاملات والتي تحققت عند معدل تغذية 0.5 مم/دورة، وسرعة قطع 500 دورة/دقيقة، وعمق قطع 0.5 مم في تحقيق توازن تكاملي يقلل من عدم انتظام السطح إلى أدنى حد ممكن. تقدم هذه النتائج إسهاماً قيماً في مجال التصنيع الدقيق، من خلال توفير إطار عمل قائم على البيانات لتعزيز سلامة السطح عند تشغيل السبائك الخفيفة، مع تقليل النفقات التجريبية إلى الحد الأدنى.

**الكلمات المفتاحية:** خراطة بالتحكم الرقمي، قطر راس العدة، تحليل التباين، التحسين خشونة السطح، سبيكة الألومنيوم والمغنيسيوم، طريقة تاغوتشي.

## 1. Introduction

Surface quality of machined components is increasingly important in modern manufacturing industries to meet the demanding requirements of sophisticated component performance, longevity, and reliability [1]. The surface finish of a machined part significantly affects its functional properties including fatigue strength, corrosion resistance, and tribological behavior [2].

Turning is one of the most fundamental machining operations in manufacturing, and the surface finish of turned components has a substantial influence on product quality. The surface roughness in turning operations is affected by numerous factors including cutting parameters (cutting speed, feed rate, depth of cut), tool geometry (nose radius, rake angle), workpiece material properties, cutting conditions (with or without coolant), and machine tool dynamics [3].

Aluminum magnesium alloys (5xxx series) are widely used in aerospace, marine, and automotive industries due to their excellent properties including high strength-to-weight ratio, good corrosion resistance, weldability, and formability [4].

These alloys, particularly Al-Mg<sub>3</sub>, are classified as "marine grade aluminum" and are extensively utilized in structural applications where both lightweight and corrosion resistance are essential [5]. The selection of appropriate cutting parameters is crucial for achieving desired surface quality while maintaining productivity. Traditional approaches to parameter selection based on experience or trial-and-error methods are often inefficient and costly.

Design of Experiments (DOE) methodologies, particularly the Taguchi method, provide systematic and efficient approaches to optimize machining parameters with minimal experimental runs [6].

This study focuses on optimizing cutting parameters for turning Al-Mg<sub>3</sub> alloy using inserts with 1.2 mm nose radius, employing Taguchi's parameter design approach to identify the optimal cutting conditions that minimize surface roughness.

## 2. Literature Review

Several researchers have investigated the effects of machining parameters on surface roughness in turning operations. Kishawy and Elbestawi [7] studied the effects of process parameters on material side flow during hard turning, concluding that proper system design can make the process insensitive to variations, thus avoiding costly rejections.

Lin [8] investigated high-speed fine turning of austenitic stainless steel and reported that excessively low feed rates below a critical value can cause chatter phenomena, deteriorating surface finish. Higher cutting speeds increase cutting temperature, which may soften the cutting tool and affect surface quality.

Yang and Tarn [9] applied the Taguchi method to optimize cutting parameters for turning operations, demonstrating that orthogonal arrays, S/N ratios, and ANOVA are effective tools for investigating cutting characteristics.

Kechagias et al. [10] optimized cutting parameters for turning copper alloy (GC-CuSn12) using Taguchi design, considering cutting speed, feed rate, depth of cut, and tool nose radius. Their findings indicated that feed rate and nose radius significantly influence surface finish.

Singh and Kumar [11] employed Taguchi's parameter design approach to optimize feed force in turned parts, concluding that selected process parameters significantly affect machining characteristics.

Zhang et al. [12] studied surface roughness optimization in end-milling using the Taguchi method, identifying feed rate and spindle speed as significant factors affecting surface roughness, while depth of cut had insignificant effects.

For aluminum alloys specifically, several studies have addressed machinability aspects. Aluminum magnesium alloys are known for their tendency to form built-up edge (BUE) at certain cutting conditions, which adversely affects surface finish [13]. The selection of appropriate cutting parameters and tool geometry is critical to minimize these effects.

The present study extends this body of knowledge by specifically investigating the effects of cutting parameters on Al-Mg<sub>3</sub> alloy using inserts with relatively large nose radius (1.2 mm), which has received limited attention in previous research.

## 3. Material and methods

### 3.1 Workpiece Material

The workpiece material used in this study was aluminum magnesium alloy (Al-3Mg), corresponding to Aluminum 5052 grade. The material was supplied as cylindrical rods with 50 mm diameter and 100 mm length. This alloy was selected due to its widespread industrial applications and its susceptibility to surface damage during machining. Table 1 presents the chemical composition, and Table 2 shows the mechanical properties of the material.

**Table 1:** Chemical composition of aluminum magnesium alloy (Al-3Mg) (weight %)

Element	Zn	Cu	Si	Mg	Pb	Fe	Ti	Mn	Al
Weight %	0.12	0.08	0.45	2.95	0.02	0.48	0.02	0.32	95.56

**Table 2:** Mechanical properties of aluminum magnesium alloy

Property	Value
Tensile Strength (N/mm <sup>2</sup> )	38
Yield Strength (N/mm <sup>2</sup> )	31
Elongation at fracture (%)	8

### 3.2 Machine Tool and Cutting Conditions

Turning experiments were conducted on a Samsung PLA25 CNC lathe (Figure 1) with maximum spindle speed of 3500 rpm and maximum power of 20 kW. All tests were performed under wet cutting conditions using coolant. Cutting inserts with nose radius of 1.2 mm were used throughout the experiments. The inserts were mounted on a suitable tool holder providing appropriate geometry for the turning operations.



**Figure 1:** CNC lathe machine (Samsung PLA25).

### 3.3 Experimental Design Using Taguchi Method

The Taguchi method was employed to design the experiments and optimize the cutting parameters. Three control factors were selected: feed rate (A), cutting speed (B), and depth of cut (C), each at three levels as shown in Table 3.

**Table 3:** Control factors and their levels

Factor	Level 1	Level 2	Level 3
Feed rate (mm/rev)	0.3	0.5	0.7
Cutting speed (rpm)	500	700	900
Depth of cut (mm)	0.5	1.0	1.5

An L9 (3<sup>3</sup>) orthogonal array was selected, which requires 9 experimental runs to study three factors at three levels. The orthogonal array design is shown in Table 4.

Since the objective was to minimize surface roughness, the "smaller-the-better" quality characteristic was selected. The signal-to-noise (S/N) ratio for smaller-the-better characteristic is calculated as:

$$S/N = -10 \log \left( \frac{1}{n} \sum_{i=1}^n y_i^2 \right)$$

Where **n** is the number of measurements and **Y<sub>i</sub>** is the measured surface roughness value.

Table 4: L9(3<sup>3</sup>) Taguchi orthogonal array

Experiment No.	Feed rate (A)	Cutting speed (B)	Depth of cut (C)
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

### 3.4 Analysis of Variance (ANOVA)

ANOVA was performed to determine the statistical significance of each control factor and to quantify their percentage contribution to surface roughness. The F-test was used to identify significant factors at a confidence level of 95%.

## 4. Results and Discussion

### 4.1 Experimental Results

Nine experiments were conducted according to the L9 orthogonal array, with three surface roughness measurements recorded for each experimental condition. The experimental results are presented in Table 5.

The results show considerable variation in surface roughness values ranging from 6.72  $\mu\text{m}$  to 14.46  $\mu\text{m}$ . The minimum surface roughness (6.72  $\mu\text{m}$ ) was achieved in experiment No. 3 with cutting parameters: feed rate = 0.3 mm/rev, cutting speed = 900 rpm, and depth of cut = 1.5 mm. Figure 3 graphically represents the average surface roughness values for all experimental runs.

Table 5: Experimental results for surface roughness (nose radius 1.2 mm)

Exp. No.	Feed rate (mm/rev)	Cutting speed (rpm)	Depth of cut (mm)	Ra1 ( $\mu\text{m}$ )	Ra2 ( $\mu\text{m}$ )	Ra3 ( $\mu\text{m}$ )	Avg. Ra ( $\mu\text{m}$ )	S/N Ratio
1	0.3	500	0.5	14.44	14.49	14.45	14.46	-23.203
2	0.3	700	1.0	8.22	8.27	8.23	8.24	-18.318
3	0.3	900	1.5	6.71	6.70	6.75	6.72	-16.547
4	0.5	500	1.0	11.71	11.72	11.76	11.73	-21.385
5	0.5	700	1.5	7.04	6.99	7.00	7.01	-16.914
6	0.5	900	0.5	12.28	12.23	12.27	12.26	-21.769
7	0.7	500	1.5	9.59	9.45	9.58	9.54	-19.591
8	0.7	700	0.5	10.51	10.55	10.50	10.52	-20.441
9	0.7	900	1.0	7.20	7.15	7.19	7.18	-17.122

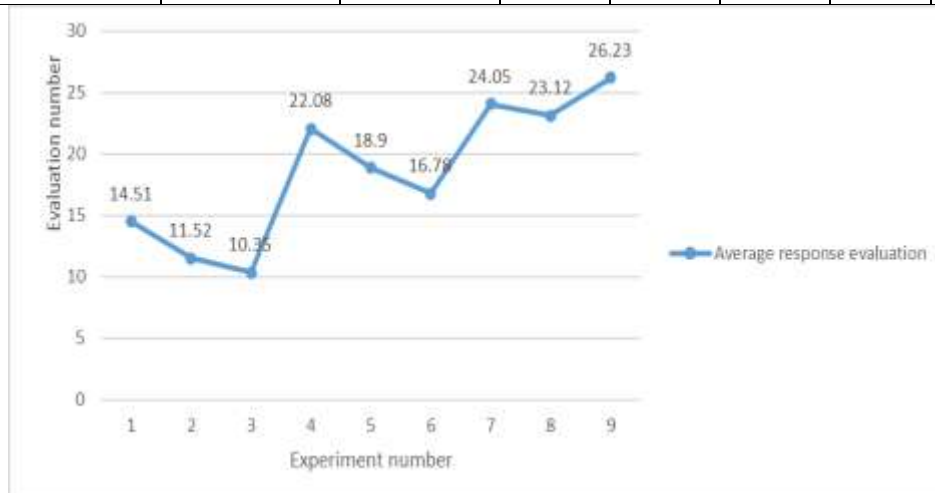


Figure 3: Average surface roughness values for experimental runs

#### 4.2 Signal-to-Noise Ratio Analysis

S/N ratios were calculated for each experimental run using the smaller-the-better characteristic. Higher S/N ratios indicate better performance (lower surface roughness and less variation). The S/N ratio values ranged from -23.203 to -16.547, with experiment No. 3 showing the highest S/N ratio (-16.547), confirming it as the best condition among the conducted experiments.

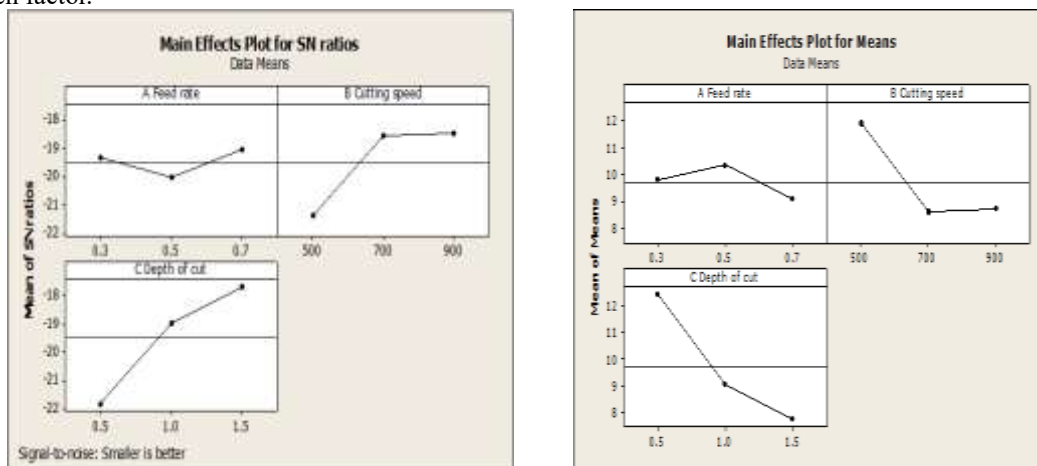
The response table for S/N ratios (Table 6) shows the average S/N ratio for each factor at each level. The delta value indicates the range of S/N ratio variation for each factor, and the rank shows the relative importance of factors.

Based on the delta values, depth of cut (C) has the highest influence on surface roughness (delta = 4.11), followed by cutting speed (B) with delta = 2.92, while feed rate (A) shows the least influence (delta = 0.96). This ranking indicates that depth of cut is the most significant factor affecting surface roughness when using inserts with 1.2 mm nose radius.

**Table 6:** Response table for S/N ratios

Level	Feed rate (A)	Cutting speed (B)	Depth of cut (C)
1	-19.36	-21.40	-21.80
2	-20.02	-18.56	-18.94
3	-19.06	-18.48	-17.69
Delta	0.96	2.92	4.11
Rank	3	2	1

**Figure 4:** shows the main effects plots for S/N ratios and mean surface roughness, illustrating the optimal levels for each factor.



**Figure 4:** Main effects plots for (a) S/N ratios and (b) mean surface roughness.

From Figure 4, the optimal parameter combination for minimizing surface roughness is:

- Feed rate at level 3 (0.7 mm/rev) - highest S/N ratio
- Cutting speed at level 3 (900 rpm) - highest S/N ratio
- Depth of cut at level 3 (1.5 mm) - highest S/N ratio

Therefore, the optimal cutting conditions are A3B3C3 (feed rate = 0.7 mm/rev, cutting speed = 900 rpm, depth of cut = 1.5 mm).

#### 4.3 Prediction of Optimal Surface Roughness

The predicted S/N ratio at optimal conditions can be calculated using the additive model:

$$\eta_{calc} = \bar{\eta}_{avg} + (\bar{A}_3 - \bar{\eta}_{avg}) + (\bar{B}_3 - \bar{\eta}_{avg}) + (\bar{C}_3 - \bar{\eta}_{avg})$$

Where:

- $\bar{\eta}_{avg}$  = average S/N ratio of all experiments = -19.4766
- $\bar{A}_3$  = average S/N ratio for feed rate at level 3 = -19.06
- $\bar{B}_3$  = average S/N ratio for cutting speed at level 3 = -18.48
- $\bar{C}_3$  = average S/N ratio for depth of cut at level 3 = -17.69

Substituting the values:

$$\eta_{calc} = -19.4766 + (-19.06 + 19.4766) + (-18.48 + 19.4766) + (-17.69 + 19.4766)$$

$$\eta_{calc} = -19.4766 + 0.4166 + 0.9966 + 1.7866 = -16.2768$$

The predicted surface roughness at optimal conditions is:

$$Ra_{pred} = 10^{-(\eta_{calc}/20)} = 10^{-(-16.2768/20)} = 10^{0.81384} = 6.51\mu m$$

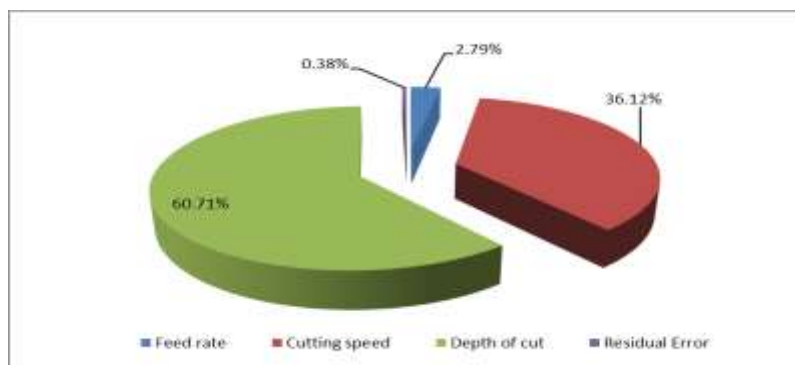
#### 4.4 Analysis of Variance (ANOVA)

ANOVA was performed to quantify the contribution of each factor to surface roughness variation. The results are presented in Table 7.

**Table 7:** ANOVA results for surface roughness

Source	DF	Seq SS	Adj MS	F-value	Contribution (%)
Feed rate	2	1.5511	0.7755	7.40	2.79
Cutting speed	2	20.0568	10.0284	95.65	36.12
Depth of cut	2	33.7103	16.8551	160.76	60.71
Residual Error	2	0.2097	0.1048	-	0.38
Total	8	55.5279	-	-	100

The ANOVA results confirm that depth of cut is the most significant factor, contributing 60.71% to the total variation in surface roughness. Cutting speed contributes 36.12%, while feed rate contributes only 2.79%. The residual error is minimal (0.38%), indicating that the selected factors adequately capture the process variability. The F-values show that all three factors are statistically significant at the 95% confidence level, with depth of cut having the highest F-value (160.76), followed by cutting speed (95.65), and feed rate (7.40).



**Figure 5:** Percentage contribution of cutting parameters to surface roughness

#### 5. Discussion

The results of this study reveal interesting findings regarding the effects of cutting parameters on surface roughness when machining Al-Mg3 alloy with inserts having 1.2 mm nose radius. The dominance of depth of cut (60.71% contribution) as the most influential factor is noteworthy and differs from many previous studies where feed rate typically emerges as the dominant factor [9,10,12].

This discrepancy can be attributed to the relatively large nose radius (1.2 mm) used in this study. Theoretical models of surface roughness in turning, such as the well-established relationship:

$$R_a = \frac{f^2}{32r}$$

Where **f** is feed rate and **r** is nose radius, suggests that feed rate effects diminish as nose radius increases. With larger nose radius, the theoretical surface roughness becomes less sensitive to feed rate variations, allowing other factors such as depth of cut and cutting speed to become more influential.

The significant contribution of cutting speed (36.12%) to surface roughness can be explained by its effect on chip formation and built-up edge (BUE) phenomena. Aluminum magnesium alloys are prone to BUE formation at certain cutting speeds, which adversely affects surface finish. Higher cutting speeds (900 rpm) reduce BUE formation, leading to improved surface quality, as observed in this study.

Depth of cut emerged as the most critical factor, which may be related to the mechanical properties of Al-Mg3 alloy. The relatively low strength of this material (tensile strength 38 N/mm<sup>2</sup>) means that increased depth of cut may cause significant material deformation and vibration, affecting surface generation. Additionally, the large nose radius combined with increased depth of cut may lead to larger contact area and higher cutting forces, influencing surface integrity.

The optimal parameter combination (A3B3C3) predicted surface roughness of 6.51 μm, which is consistent with the best experimental result (6.72 μm from experiment No. 3). This close agreement validates the additive model and confirms the reliability of the Taguchi optimization approach.

From a practical perspective, these findings suggest that when using inserts with large nose radius for machining Al-Mg3 alloy, priority should be given to controlling depth of cut and cutting speed rather than focusing primarily on feed rate reduction. This insight can help manufacturing engineers optimize their turning operations for improved surface quality while maintaining productivity.

## 6. Conclusions

This study investigated the optimization of cutting parameters for surface roughness in CNC turning of aluminum magnesium alloy (Al-Mg<sub>3</sub>) using inserts with 1.2 mm nose radius. The following conclusions can be drawn:

1. The Taguchi method with L9 orthogonal array successfully optimized the cutting parameters for minimum surface roughness with only nine experiments.
2. Depth of cut was identified as the most significant factor affecting surface roughness, contributing 60.71% to the total variation, followed by cutting speed (36.12%) and feed rate (2.79%).
3. The optimal cutting parameters for achieving minimum surface roughness were feed rate of 0.7 mm/rev, cutting speed of 900 rpm, and depth of cut of 1.5 mm (A3B3C3).
4. The predicted surface roughness at optimal conditions was 6.51  $\mu$  m, which closely matches the experimental value of 6.72  $\mu$  m, validating the optimization approach.
5. The relatively low contribution of feed rate to surface roughness is attributed to the large nose radius (1.2 mm), which reduces the theoretical surface roughness sensitivity to feed rate variations.
6. ANOVA results confirmed that all three cutting parameters are statistically significant at the 95% confidence level, with depth of cut having the highest F-value (160.76).
7. The minimal residual error (0.38%) indicates that the selected factors adequately represent the process variability.

These findings provide valuable insights for manufacturing engineers working with aluminum magnesium alloys, particularly when using inserts with larger nose radii. The optimal cutting conditions identified in this study can be implemented in industrial settings to achieve improved surface quality in turned components.

## 7. Recommendations for Future Work

Based on the findings of this study, the following recommendations are proposed for future research:

1. Investigate the effects of cutting parameters on surface roughness for other aluminum alloy series (2xxx, 6xxx, 7xxx) to establish comprehensive machining guidelines.
2. Study the interaction effects between nose radius and cutting parameters by conducting experiments with multiple nose radii (0.4 mm, 0.8 mm, and 1.2 mm) under identical conditions.
3. Evaluate the influence of cutting conditions on other surface integrity characteristics such as residual stress, microhardness, and subsurface damage.
4. Investigate the effects of dry versus wet machining conditions on surface roughness when using large nose radius inserts.
5. Develop predictive models using artificial intelligence techniques (neural networks, fuzzy logic) for surface roughness estimation based on cutting parameters.
6. Study tool wear progression and its effect on surface roughness over extended machining periods.
8. Conduct economic analysis to balance surface quality requirements with productivity considerations.

## Compliance with ethical standards

### Disclosure of conflict of interest

The authors declare that they have no conflict of interest.

## References

1. Doyle, L.E., 1985. Manufacturing Processes and Materials for Engineers. University of Illinois, pp. 508-510.
2. Jayant, A., Kumar, V., 2008. Prediction of Surface Roughness in CNC Turning Operation using Taguchi Design of Experiments. IE(I) Journal-PR, Volume 88.
3. Reddy, B.S., Kumar, J.S., Reddy, K.V.K., 2009. Prediction of Surface Roughness in Turning Using Adaptive Neuro-Fuzzy Inference System. Jordan Journal of Mechanical and Industrial Engineering, Volume 3, No. 4.
4. Srikanth, T., Kamala, V., 2008. A Real Coded Genetic Algorithm for Optimization of Cutting Parameters in Turning. IJCSNS International Journal of Computer Science and Network Security, Vol. 8 No. 6.
5. Metals Handbook, 9th Edition. Volume 16: Machining. ASM International.
6. Roy, R.K., 2001. Design of Experiments Using the Taguchi Approach: 16 Steps to Product and Process Improvement. John Wiley & Sons.
7. Kishawy, H.A., Elbestawi, M.A., 1999. Effects of process parameters on material side flow during hard turning. International Journal of Machine Tools and Manufacture, 39(7), pp. 1017-1030.
8. Lin, W.S., 2008. The study of high speed fine turning of austenitic stainless steel. Journal of Achievements in Materials and Manufacturing Engineering, Volume 27, Issue 2.
9. Yang, W.H., Tarnq, Y.S., 1998. Design optimization of cutting parameters for turning operations based on the Taguchi method. Journal of Materials Processing Technology, 84, pp. 122-129.
10. Kechagias, J., Iakovakis, V., Petropoulos, G., Aropoulos, S., 2009. A parameter design in turning of Copper alloy. International Conference on Economic Engineering and Manufacturing Systems, Brasov, pp. 26-27.

11. Singh, H., Kumar, P., 2006. Optimizing feed force for turned parts through the Taguchi technique. *Sadhana*, Volume 31, Part 6, pp. 671-681.
12. Zhang, J.Z., Chen, J.C., Kirby, E.D., 2006. Surface roughness optimization in an end-milling operation using the Taguchi design method. *Journal of Materials Processing Technology*, 184, pp. 233-239.
13. Thiele, J.D., Melkote, S.N., Peascoe, R., Watkins, T.R., 2000. Effect of cutting edge geometry and workpiece hardness on surface residual stress in finish hard turning of AISI52100 steel. *Transactions of the ASME*, Vol. 122, pp. 642-649.
14. Kirby, E.D., 2010. Optimizing the Turning Process Toward an Ideal Surface Roughness Target. *Journal of Industrial Technology*, Volume 26, Number 1.
15. Suhail, A.H., Ismail, N., Wong, S.V., Abdul Jalil, N.A., 2010. Optimization of cutting parameters based on surface roughness and assistance of workpiece surface temperature in turning process. *American J. of Engineering and Applied Sciences*, 3(1), pp. 102-108.
16. Gusri, A.I., Che Hassan, C.H., Jaharah, A.G., Yanuar, B., Yasir, A., Nagi, A., 2008. Application of Taguchi method in optimizing turning parameters of Titanium alloy. *Engineering Mathematics Group*.
17. Nalbant, N., Gokkaya, H., Sur, G., 2006. Application of Taguchi method in the optimization of cutting parameters for surface roughness in turning. *Materials and Design*.
18. Peace, G.S., 1993. *Taguchi Methods: A Hands-On Approach to Quality Engineering*. Addison-Wesley.
19. Lindman, H., 1992. *Analysis of Variance in Experimental Design*. Springer-Verlag, New York.
20. Walsh, R.A., 1997. *Machining and Metal Working Handbook*. McGraw-Hill.
21. Shaw, M.C., 1994. *Metal Cutting Principles*. Clarendon Press, Oxford.
22. Sekhon, G.S., Seth, N., *Fundamentals of Metal Cutting and Machine Tools*, 2nd Edition. New Age International Publishers.
23. Lou, M.S., Chen, J.C., Li, C.M., 1999. Surface Roughness Prediction Technique for CNC End-Milling. *Journal of Industrial Technology*, Vol. 15, No. 1.
24. American Society of Mechanical Engineers, 1985. *Surface Texture (Surface Roughness, Waviness and Lay)*. ANSI/ASME B46.1-1985.

**Disclaimer/Publisher's Note:** The statements, opinions, and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of **LJCAS** and/or the editor(s). **LJCAS** and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions, or products referred to in the content.